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THE METHOD OF FINDING THE LONGITUDE AT SEA, BY TIME-KEEPERS:

TO WHICH ARE ADDED,

TABLES OF EQUATIONS
TO
EQUAL ALTITUDES.

More extenſive and accurate than any hitherto publiſhed.

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BRITISH MUSEUM

PREFACE.

IN the following tract I have ſhewn, in as plain and clear a manner as I am able;

First, What longitude is.

Secondly, What is underſtood by the term, Finding it: that is, in what manner, and from what circumſtances the knowledge of it is derived.

And, thirdly, The method of applying a watch, or time-keeper, to this purpoſe; which naturally includes the means and method of finding the rate which the time-keeper goes at, and how much it is too faſt or too ſlow for mean time at the place the ſhip ſails from before the voyage commences. This, indeed, is the only difficult part of the buſineſs: for the method of finding the longitude by a time-keeper, when the time-keeper is regulated to keep mean time, and ſet to mean time at the firſt meridian; or when its daily deviation from mean time at the firſt meridian is given, is too plain to be miſunderſtood, and too ſimple an operation to require rules for putting it in practice. Even the buſineſs of finding the *rate*, as it is called, has ſo little of what is really difficult in it, that ſome of the officers in the Eaſt-India Company's ſervice conſtantly found the rates of their time-keepers themſelves, without any thing having been written expreſsly concerning it: nor ſhould I have thought it neceſſary to write on the ſubject now, if ſome very extraordinary opinions had not been lately advanced relative to it. The opinions here hinted at are, indeed, ſo very extraordinary, and at the ſame time ſo void of foundation, that they would neither have deſerved, nor obtained notice, if they had not received countenance, and even ſupport, from authority, in itſelf the moſt reſpectable, though, in what relates to ſcience, not infallible. By what means, or for what purpoſe they obtained ſuch countenance and ſupport, it is neither my buſineſs or intention to enquire: but, meeting with it, they have certainly done more than could even have been expected toward bringing time-keepers into diſrepute, and toward defeating the endeavours of the Board of Longitude, who have been labouring inceſſantly for the laſt thirty years to eſtabliſh the uſe of them, and to encourage improvements in their conſtruction. Indeed, every one who has to make uſe of them, muſt perceive immediately, that if the new doctrine be true, time-keepers muſt be of very little uſe at ſea, as a means of diſcovering the longitude: and it was the experience, alone, which ſeamen had already had of their utility, in direct oppoſition to theſe opinions, that has preſerved their reputation.

In proof of what is here advanced, I can aſſure the reader, that I have heard more doubts expreſſed, and more difficulties ſtarted relative to what is called the rate of a time-keeper's going, the proper mode of obtaining it, and the degree of dependence which may be placed on them, in the laſt twelve or eighteen months, than in all my life before, though I have been pretty intimate with the ſubject for near forty years: and I am firmly perſuaded that if the uſe of time-keepers had not been well eſtabliſhed by experience before theſe new doctrines were broached, they would not have been ſpeedily introduced into practice now.

To remove the ſtigma which, for private purpoſes, has been unjuſtly thrown on theſe valuable machines, by thoſe who, notwithſtanding, would be thought, and indeed ought, to have acted differently by them; to ſave myſelf, if poſſible, ſome trouble in future; and to enable thoſe whoſe buſineſs it is to apply them to the purpoſe of finding the longitude, in the beſt, and eaſieſt manner, were my motives for writing the following tract. But as my firſt object may be thought by ſome to be of a controverſial nature, I ſhall confine what I have to ſay on it to this place, and to as few words as poſſible: it is compriſed under the four following heads:

1. It has been repreſented, that to render the uſe of a time-keeper reaſonably certain, the rate of its going ought to be taken from a period of time, at leaſt, equal to that of the voyage which it is intended to be uſed in*.

If this were true, it would be neceſſary for the Captains, and Officers, of Eaſt-India ſhips, to begin to examine the rates of their time-keepers, or to employ people to do it for them, at leaſt four or five, or indeed ſix months before the time they are appointed to ſail, becauſe the outward bound voyage may generally be expected to laſt ſo long: but this is often four, five, or ſix times as long as they know of their appointments before the time when they are directed to have every thing on board, and be ready to ſail. On board ſhips of war, which are frequently ordered out of port on a few days notice, and remain out for months together, the objection is ſtill ſtronger. And in voyages of Diſcovery, where time-keepers are more eſpecially neceſſary, and in which ſhips are ſeldom in a port more than a fortnight or three weeks at a time, and at ſea four or five months, they would, according to this doctrine, be totally uſeleſs. So abſurd are aſſertions, ſometimes, when they are made to ſerve particular purpoſes; becauſe few of the conſequences which may be drawn from them, except that which they are intended to ſerve, are conſidered.

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* See Mr. Mudge's "Narrative of Facts," p. 22, &c.

2. It has been repreſented as a matter of great difficulty to aſſign the rate which a time-keeper may be expected to keep in future *. It has even been aſſerted that "no general rule has been laid down, nor ſeems capable of being found, for aſſigning, from any number of trials, the rate which the watch ſhall be moſt likely to obſerve in any future trial;" and that the common way, of dividing the whole that a watch has done, during a given period, by the number of days, and applying the quotient as a daily rate to be uſed in any period ſucceed-

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* See the Report of Mr. Mudge's Committee to the Houſe of Commons, p. 7.

ing, is certainly not a method that can pretend to any extraordinary exactneſs *.

It will be ſhewn in the following tract, that there is nothing more ſimple in itſelf, or more eaſily performed, than finding the rate, which a time-keeper goes at: and I aſſert, without fear of being confuted, that the rate, ſo found, is ſufficiently exact for the purpoſe it is intended for, if the time-keeper be ſo. For every one, who is converſant with aſtronomical obſervations, knows that the time can be always found within a very ſmall part of a ſecond. But, that I may not under rate it, I will ſuppoſe that an error of half a ſecond may be committed in finding the time, both at the beginning and end of the interval which the rate is taken from, and that the obſerver is ſo unfortunate as to make it different ways, which will create an error of one ſecond in the whole interval: this error, which few who are acquainted with the ſubject will admit can happen, will only cauſe an error of twelve ſeconds, or three minutes of longitude in a voyage of a whole year, the rate being taken from a month, as is uſual. And I aſſert, that this is a general rule for finding the rate which a time-keeper is moſt likely to go at in future. If, indeed,

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* Report of Mr. Mudge's Committee, p. 9.

the irregularities in a watch's going be very great, or the period in which its irregularities return be long, or infinite, I grant that this method of deriving a rate is uſeleſs; and ſo will every other method be: it is, indeed, impoſſible to find the ſum of a ſeries the terms of which bear no relation one to another; but the method is only uſeleſs becauſe the watch is ſo, at leaſt for the purpoſe under conſideration! It is impoſſible to avoid expreſſing ſome ſurpriſe at finding ſuch an obſervation made.

3. It has been ſaid that it is not well-agreed what the object and purpoſe is which the taking of a rate is intended to anſwer *: and that among perſons likely to be beſt informed on the ſubject, great diverſity of opinion prevails in regard to what ought to be taken for the rate of going of a watch; and that even the ſame perſons fluctuate, at times, between opinions widely different from each other concerning it †.

I am not in fear of being confuted when I aſſert, that every diſintereſted perſon, who underſtands the ſubject, will agree perfectly concerning the purpoſe which taking the rate of a watch is intended to

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* Report of Mr. Mudge's Committee, p. 9.

† Ibid. p. 10.

anſwer, notwithſtanding he may expreſs himſelf obſcurely, or even incorrectly, in anſwering directly to queſtions which are put to him, without previous notice, on ſcientific ſubjects. Queſtions of ſuch a nature ought never to be put in this manner, but be given in writing; and the anſwers ſhould be returned in the ſame manner, after due deliberation, if correct information be expected on the ſubject. I am in as little danger of being confuted, when I ſay that every perſon of the above deſcription, will agree alſo about the rate which ought to be taken of a time-keeper to go to ſea with. But there may be, and undoubtedly is, in the inſtance under conſideration, a material difference between the means which ought to be made uſe of for trying how far a machine is adequate to a certain purpoſe, and in applying it to that purpoſe in the beſt manner circumſtances will admit of, when the machine is known to be, in ſome degree, imperfect: and if ſo, a man cannot be ſaid to fluctuate between "opinions widely different," becauſe, on being aſked what he thinks the beſt method of trying how far a time-keeper is deſerving of that name he propoſes one method; and, on being aſked, afterward, what he thinks the beſt method

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* Report of Mr. Mudge's Committee, p. 10.

of applying an imperfect time-keeper to the purpoſe it was intended for, he propoſes another, ſomewhat different. This, however, is a juſt ſtatement of the only caſe which has been brought forward to prove that "the ſame perſons fluctuate at times between opinions widely different from each other:" for, in the firſt caſe, the opinion of the perſon alluded to had been aſked concerning the beſt means of trying the merits of a time-keeper; and in the latter concerning the means of finding a rate which the time-keeper was moſt likely to conform to in future. The perſon, unfortunately, did not perceive that the queſtion had been ſhifted on him: and I am perſuaded the gentlemen who examined him were not aware that they had done it; for, if they were, the inference they have drawn would be very uncandid. Not a ſingle inſtance has been adduced to ſhew, that "great diverſity of opinion prevails, in regard to what ought to be taken for the rate of going of a watch, among perſons likely to be beſt informed on the ſubject; nor does it appear to me that one can.

4. It has been aſſerted that when ever a ſhip touches at a port, the longitude of which is known, a new rate of a time-keeper may be obtained; and that if a per-

ſon land at a place where the longitude is not known, though but for a few hours, the longitude may be determined within leſs than a quarter of a degree, and a new rate of the time-keeper found from it *.

The falſehood of theſe aſſertions, and the ignorance they betray of the ſubject they relate to, are too groſs to impoſe on any who underſtand that ſubject; and would not have been taken notice of here, were it not that many perſons have occaſion to uſe time-keepers who are not competent to determine how far ſuch aſſertions are true or falſe; and therefore may be miſled by the boldneſs which they are made with.

To prove the futility of the firſt of them, namely, that a new rate of going may be obtained for a time-keeper every time a ſhip touches at a port where the longitude is known, I need only put the following caſe: Suppoſe a ſhip to ſail from England, and reach the Cape of Good Hope in ſixty days, when it is diſcovered that the longitude ſhewn by the time-keeper is 30 minutes wrong; or that the watch has erred two minutes in time. It will be obvious to every one, that if the time-keeper altered its rate immediately on

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* See the Appendix to the Report of Mr. Mudge's Committee, p. 120, 121.

leaving England, and continued to go uniformly afterward, it muſt have altered its rate exactly two ſeconds a-day. If it did not alter its rate till one-third part of the time had elapſed, and went uniformly afterward, it muſt have altered its rate three ſeconds a-day. If it did not alter its rate till half the time was expired, it muſt have altered its rate four ſeconds a-day. If not till two-thirds of the time were elapſed, it muſt have altered its rate ſix ſeconds a-day: and if not till the day before they arrived at the Cape, which is as probable as the firſt ſuppoſition, it muſt have altered its rate of going *two minutes* a-day! If we conceive the watch to have altered its rate by degrees (which is moſt probable;) or if we admit the probability, (which is no ſmall one) that it might firſt go faſter and afterward ſlower; or firſt ſlower and afterward faſter, than it was going at the commencement of the voyage, the quantity by which a rate, ſo obtained, may be uncertain, as well as the number of ways it may happen, cannot be computed. It is eaſy to conceive that ſuch an opinion might have been advanced if a man had been taken by ſurpriſe, and the queſtion had come upon him unexpectedly: but that an aſſertion ſo prepoſterous, could be made premeditatedly, and repeatedly, after the matter had been canvaſſed, to invalidate the teſtimony of others, who had denied the poſſiblity of doing it, would be ſcarcely credible, if it did not ſtand on record under as good authority as any in the kingdom.

In reſpect to the other aſſertion, namely, that the longitude may be found, with certainty to leſs than a quarter of a degree, whenever a perſon can land, though it be but for a few hours; it may be obſerved that correſponding obſervations are out of the queſtion, becauſe the longitude is to be determined on the ſpot, for the purpoſe of finding a new rate for the time-keeper, to be uſed in the future part of the voyage: conſequently, theory muſt be reſorted to for the time under the firſt meridian. This being premiſed, every aſtronomer who knows the preſent ſtate of the lunar theory, and has had much practice in obſerving the diſtance of the moon from the ſun and ſtars, will ſmile at the idea of determining the longitude of a place *with certainty*, *to leſs than a quarter of a degree*, whenever he can land for *a few hours*. Had the Gentlemen, before whom this was advanced, been inclined to ſift too narrowly into things, might they not have aſked this acute obſerver what occaſion there can be for time-keepers, if this boaſt be true? Or why it was neceſſary to land to do it? Becauſe every one who knows any thing of the matter has long known, that "the motion of a ſhip is no otherwiſe an impediment in this ſort of obſervations, than as it renders the repetition of them more tedious and troubleſome to the obſerver*. And if the longitude of a ſhip can be determined with ſo much accuracy, and in ſo little time, whenever a man chuſes to do it, ſurely there can be no occaſion for him to put himſelf to the expence and trouble of a time-keeper. But we are told further, that "if they have proper inſtruments they may determine it by Jupiter's Satellites." In fixed obſervatories, where the obſerver has every advantage and convenience, about nine or ten of theſe obſervations are, on a medium, obtained in the courſe of a whole year; and out of this number, ſmall as it is, it is not unuſual for ſome of them to differ from the tables conſiderably more than the quantity here mentioned: and if this be the caſe in fixed obſervatories, where they are certain of their time to leſs than one ſecond; what muſt the deviation be when this article is alſo, in ſome degree, uncertain, and the obſervations made under many diſadvantages?

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* See Dr. Bradley's Letter to the Board of Admiralty concerning Admiral Campbell's Obſervations, at the end of Mayer's Tables.

I have only further to add, that all the neceſſary tables, which are not found in the Requiſite Tables, are added at the end: and it is to be noted, that when a table is referred to which is in the Requiſite Tables, that book is referred to by name; and when the name of that book does not occur, the table, then referred to, will be found at the end of this work.

The tables of equations to equal altitudes are more extenſive than any which have hitherto been publiſhed; and I flatter myſelf will be found exceeding accurate. They are general; and will be found uſeful to many perſons beſide ſeamen.

Throughout the whole I have had practice in view; and truſt I have, in no inſtance, contented myſelf with barely telling my reader he muſt do ſuch, and ſuch things, without explaining the manner in which he is to do them: knowing, from much experience, that inſtructions of this kind, and eſpecially in what relates to the uſe of aſtronomical inſtruments, cannot be underſtood by any but thoſe who are tolerably well acquainted with the ſubject before hand: ſuch do not want any inſtructions, and will, I truſt, excuſe my prolixity when they know my motives for it.

THE METHOD

OF FINDING THE LONGITUDE AT SEA,

BY

A TIME-KEEPER.

1. THE Earth is a body compoſed partly of land and partly of water, of a globular figure; and it revolves on an imaginary line, paſſing through its center, as an axis, once in the courſe of a natural day.

2. The two points where this imaginary axis meets the ſurface of the earth are called its poles: that which is neareſt to Europe being called the *north* pole, and the other is called the *ſouth* pole.

3. If a circle be ſuppoſed to circumſcribe the earth, exactly in the middle between the two poles, that circle is called the Equator: the circle which correſponds to it in the heavens, is called the Equinoctial.

4. The Ecliptic, is that circle in the heavens which the earth deſcribes in its annual motion round the ſun; being the ſame with that which is apparently de-

ſcribed by the ſun in a year: it cuts the equinoctial in two points which are directly oppoſite each other. That point where the ecliptic cuts the equinoctial, and paſſes to the northward of it; is called the vernal equinoctial point; and the other, where it cuts the equinoctial, and goes to the ſouthward of it, is called the autumnal equinoctial point.

5. The ecliptic is divided into twelve equal parts, called ſigns; each ſign into 30 degrees, each degree into 60 minutes, and each minute into 60 ſeconds. Every circle is ſuppoſed to be divided into 360 degrees, a degree into 60 minutes, and each minute into 60 ſeconds, and ſo on.

6. The ſun's longitude is an arch of the ecliptic, contained between the vernal equinoctial point and the center of the ſun: it is expreſſed in ſigns, degrees, minutes, and ſeconds; and is given on p. II. of the Nautical Almanac for the noon of every day at Greenwich.

7. Circles deſcribed on the ſurface of the earth to paſs through both poles, are called meridians. The circles which correſpond to theſe in the heavens, are called hour-circles, and circles of right-aſcenſion. A circle of this kind may be deſcribed

through any place on the earth, and it is then called the meridian of that place which it is deſcribed through.

8. That arch of the meridian which is intercepted between any place and the equator, or the number of degrees, minutes, &c. which are contained in it, is called the latitude of that place.

9. The horizon is that circle which bounds the view of an obſerver when he is on the ſea, or an open plane.

10. The altitude of the ſun, or a ſtar, is the number of degrees, minutes, &c. that its center is above the horizon, at any time: when the object is on the meridian of the place, its altitude is the greateſt it can have that day; and is called its meridional altitude.

11. The right-aſcenſion of the ſun, or a ſtar, is an arch of the equinoctial contained between the vernal equinoctial point, and that point of it which comes to the meridian at the ſame time with the object; or it is the degrees, minutes, &c. contained in that arch. It is ſometimes given in time, reckoning one hour for every 15 degrees; and is thus given for the ſun, on page II. of the Nautical Almanac every day at noon, under the me-

ridian of Greenwich. The right-aſcenſions of ſuch ſtars as are wanted in this tract are given in Table V.

12. The declination of the ſun, or a ſtar, is the number of degrees, minutes, &c. which its center is north or ſouth of the equinoctial. The declination of the ſun is given for the noon of every day at Greenwich on page II. of the Nautical Almanac; and the declinations of ſuch ſtars as are wanted in this tract will be found in Table V.

13. That part of the equator which is intercepted between the meridian of any place, and the meridian of the place where longitude is ſuppoſed to begin, or the number of degrees, minutes, &c. contained in it, is called the longitude of that place.

14. Formerly all Geographers reckoned their longitude from the meridian of the iſland of Ferro, the moſt weſterly of the Canary Iſlands, becauſe it was the moſt weſterly land that was known when that practice was adopted; and the longitude was reckoned wholly eaſtward, up to 360 degrees. The Dutch, German, and ſome other Geographers, ſtill reckon their longitude in this manner; but others reckon it from the meridian of the capital city of

their own country, both eaſtward and weſtward, to 180 degrees; and the Engliſh generally reckon it from the meridian of the Royal Obſervatory at Greenwich, becauſe all tables are adapted to that meridian, and all the computations in the Nautical Almanac are made for it.

15. To explain theſe things more particularly, let ENQS, fig. 1. repreſent the earth, P the north pole, the oppoſite point to which, or the ſouth pole, falling behind the figure, is not ſeen. EAQ will then repreſent the equator, which being equally diſtant from the two poles, and they 180 degrees aſunder, muſt evidently be every where 90 degrees from each of them. PO, P 15, P 30, &c. are meridians; PO being that of Greenwich, at which longitude begins according to the Engliſh way of reckoning it, and from which it is always counted.

16. If the point B be ſuppoſed to repreſent the iſland of Barbadoes, PB 60 will repreſent the meridian of that iſland, and the arch B 60 will be its latitude; and as the iſland lies on the north ſide of the equator, the latitude will be north: A 60, the arch of the equator intercepted between the meridians of Greenwich and

Barbadoes, will be its longitude; which is weſt, becauſe Barbadoes lies to the weſt of the meridian of Greenwich.

17. As the earth revolves on its axis from weſt to eaſt once in the courſe of a natural day, or 24 hours, it is manifeſt that the meridian of every place on the earth will come oppoſite to the ſun once in that time: and becauſe that whenever the meridian of any place comes oppoſite to the ſun it is noon at that place, it follows that when the line N P A S, which is the meridian of Greenwich, comes oppoſite to the ſun it will be noon at Greenwich, and a new day will commence. It muſt be farther obſerved, that as the motion of the earth on its axis is uniform, equal parts of the equator will paſs by the ſun in equal ſpaces of time; and, conſequently, that one twenty-fourth part of it, or 15 degrees, will paſs by the ſun in one hour. Hence, at the end of one hour after the time when it was noon at Greenwich, the meridian P 15 C, which is 15 degrees weſt of the meridian of Greenwich, will come oppoſite the ſun, and make noon to all the places which are on that meridian, and a new day will commence at thoſe places exactly one hour after it commenced at Greenwich. In like manner,

two hours after the time when it was noon at Greenwich, the ſun will arrive at the meridian P 30 D, which is 30°. weſt of the meridian of Greenwich, and make noon to all the places that are on it; and a new day will commence at thoſe places, when it is two o'clock in the afternoon at Greenwich: the ſame reaſoning will hold good for places which are ſtill farther weſt; and it is therefore evident, that the difference of longitude between any two places, bears the ſame proportion to the difference between the times at theſe two places that 15 degrees bear to an hour of time. Conſequently, if the difference between the times at two places be turned into degrees, minutes, &c. at the rate of 15 degrees to an hour, it will be the difference of longitude between thoſe places: and it is farther manifeſt, that if the time at the meridian of Greenwich be greater than the time at the ſhip, or other place, the ſhip or place lies to the weſt of Greenwich; but if the time at the ſhip or place be greater than the time at Greenwich, the ſhip or place lies to the eaſt of Greenwich; becauſe the time of noon at that place muſt have preceded the time of noon at Greenwich.

18. Hence it appears, that to find the longitude of any place from another given one, as Greenwich, we muſt find the time of the day at each place, take the difference between theſe two times, and turn it into degrees and minutes by allowing 15 degrees for every hour, or one degree for every 4 minutes of time, and one minute for every four ſeconds of time.

19. The time at the ſhip, or place where the obſerver is ſituated, may be found from an obſervation of the ſun's altitude in the day time, or from the altitude of a known fixed ſtar in the night, by rules which will be given hereafter: for finding the time at the firſt meridian, many methods have been propoſed; but two only have yet been found to perform it with reaſonable accuracy. One is by obſerving the diſtance of the moon from the ſun, or a fixed ſtar; and the other is by means of a Watch, or Time-keeper: it is this latter method, only, which I ſhall conſider at preſent. But before I ſhew how the time is to be found at the firſt meridian by a Time-keeper, it will be neceſſary to explain the difference between mean and apparent time; to ſhew how one may be derived from the other; and how the apparent time may be

found at any place where the obſerver is ſituated.

20. Apparent Time, called by foreign Aſtronomers *true time*, is that which is derived immediately from the ſun, either by obſerving its tranſit over the meridian, which happens at the inſtant of apparent noon, when a new day commences, or by obſerving its altitude at a diſtance from the meridian.

21. Mean Time is that which is ſhewn by good clocks or watches, properly regulated: It is ſometimes called equated time, the reaſon for which will appear preſently.

22. As the earth revolves uniformly on its axis, if it had no annual motion in its orbit, or if that motion was uniform, and in a plane which is parallel to the plane of the equinoctial, the natural days would neceſſarily be always of the ſame length; and the apparent and mean time would be the ſame. But experience has ſhewn that this is not the caſe, and that the time which elapſes between the ſun's being on the meridian of any place, and its return to it again, is conſiderably longer ſometimes than it is at others.

The annual motion of the earth is not perceived by us, who are upon it; but it is the cauſe of an apparent motion in the ſun, the ſame way; namely, eaſtward, and of the ſame quantity: Conſequently, when the earth, by its diurnal rotation on its axis, has brought any place on its ſurface oppoſite to the point where the ſun was at the preceding noon, the inhabitants of that place will not find the ſun there, but will have to follow it, ſtill farther eaſtward, by a quantity which is equal to the ſun's apparent diurnal motion in its orbit, before the place they inhabit will come oppoſite to it. And, as it has been obſerved, this motion is not only unequal in itſelf, but rendered, apparently, ſtill more ſo by the obliquity of its direction, it is obvious the earth will have to follow the ſun ſometimes a longer, and ſometimes a ſhorter ſpace before the ſame point on its ſurface will come oppoſite to it; and, of courſe, the lengths of natural days will be ſometimes longer, and ſometimes ſhorter alſo. But as all good clocks and watches go uniformly, the mean day of 24 hours, which is ſhewn by them, muſt, neceſſarily be always of the ſame length: it, therefore, follows, that when the ſun's apparent motion in its orbit is ſlow, and the earth, in conſequence, has a leſs ſpace to follow it before any given place on its ſurface comes oppoſite to the ſun, the ſun will at ſuch times be on the meridian of that place before the end of the 24 mean hours; and when the ſun's apparent motion in its orbit is quickeſt, and when, of courſe, any given place on the earth's ſurface has a greater ſpace to follow the ſun before it comes oppoſite to it, the ſun will not be on the meridian of that place, till ſome time after the 24 hours are ended.

23. This inequality in the lengths of natural days, is called the equation of time; and the quantity of it, that is, the time by which the ſun appears to be on the meridian of any place before or after the end of 24 mean hours, is inſerted on the ſecond page of every month in the Nautical Almanac, for the noon of each day, at Greenwich. It is marked *ſubtractive*, when the ſun comes to the meridian ſooner, and *additive* when it comes to the meridian later than the time of mean noon, or twelve o'clock as it is uſually called: and the meaning is, that the quantity of time expreſſed by this equation is to be ſubtracted from the apparent time, or that which is immediately derived from the ſun, to obtain the mean time, ſhewn by clocks and watches,

in the former caſe, and added to it in the latter.

If the equation of time be taken from 24^h^ when it is ſubtractive, the remainder will be the mean time when the ſun's center will be on the meridian of the place: when the equation is additive, the equation is itſelf, the mean time of apparent noon.

PROBLEM I.

24. To take the equation of time out of the Nautical Almanac, for any given place and time.

RULE.

If the time at Greenwich be not given, turn the longitude of the place into time; and add it to the time at the given place, if the longitude be weſt, but ſubtract it from that time, if the longitude be eaſt, and it will give the time at Greenwich.

Take the equation of time from page II. of the Nautical Almanac, for the noon preceding the time when it is wanted, and alſo the difference between it and the equation for the day following; and ſay, as 24^h is to this difference, ſo is the time at Greenwich to a fourth number; which muſt be added to, or ſubtracted from, the equation for the preceding noon, according as the equation is increaſing or decreaſing.

Note. In every operation, where one time is to be taken from another, add 24 hours to the time you ſubtract from, if the time which is to be taken from it be the greater; and the remainder muſt be reckoned from the noon of the preceding day. When one time is added to another, if the ſum exceed 24 hours, take 24 hours from it, and the remainder muſt be reckoned from the noon of the following day.

EXAMPLE I.

What was the equation of time on the 27th of December, 1793, when it is 27′. paſt 10 o'clock at Greenwich?

Equation of time for noon, Dec. 27th, 1793, add.	1′ 50″, 5
24^h is to 29″,5 (daily diff.) as 10^h 27′ is to	+ 12 , 8
The equation ſought	+2 3 , 3

EXAMPLE II.

What was the equation of time on the 13th of November, 1793, at noon, at Calcutta, longitude in time 5^h 54′?

Equation of time for noon at Greenwich......	15′ 21″, 5
24^h is to 5^h 54′ as 9″ (daily diff.) to	+ 2 , 2
Equation of time for noon at Calcutta	15 23 , 7

EXAMPLE III.

What was the equation of time on the 14th of July, 1794, at 18^h 46′ at Mexico?

Time at Mexico, July 14th, ...	18^h 46′	
Long. of Mexico in time	6 40	
Time at Greenwich, July 15th,	1 26	
Equation of time, July 15th, at noon, add......		5′ 29″, 6
24^h is to 5″,7 (daily diff.) as 1^h 26′ is to ..... +		0, 3
The equation ſought, add		5 29, 9

PROBLEM II.

25. To find the ſun's longitude for noon at any given place from the Nautical Almanac.

RULE.

Take the ſun's longitude from page II. of the Nautical Almanac for the given day, and its hourly motion from page III.

Enter Table III. with the ſun's hourly motion at the top, and the longitude of the given place in the left-hand-ſide column, and take out the correction which ſtands under the former and oppoſite the latter: this correction being added to the ſun's longitude for noon at Greenwich, if the longitude of the place be weſt, or ſubtracted from it if the longitude be eaſt, will give the ſun's longitude for noon at the given place.

EXAMPLE I.

What was the ſun's longitude at noon on the 15th of October, 1793, at Lima, in Peru?

Sun's longitude for noon at Greenwich		$6^s\ 22^\circ\ 34',8$
Hourly mot. 2′ 29″ and long. 77° W. give	+	12, 7
Sun's long. for noon at Lima		6 22 47, 5

EXAMPLE II.

What was the ſun's longitude on the 27th of November, 1793, at Calcutta?

Sun's longitude for noon at Greenwich		$8^s\ 5^\circ 46',6$
Hourly motion 2′ 32″ and long. 88° E. give	—	14, 9
Sun's longitude for noon at Calcutta		8 5 31, 7

PROBLEM III.

26. To find the ſun's declination for any given time and place from the Nautical Almanac.

RULE.

Take the ſun's declination out of the Nautical Almanac for noon at Greenwich on the given day, if the given time be leſs than 12 hours, but for the day following if it be more.

Enter Table VI. of the Requiſite Tables with the time from the neareſt noon at the top, and the day of the month in one of the ſide columns: under the former, and oppoſite to the latter, ſtands the correction of the ſun's declination on account of the time.

If the ſun's declination be wanted for noon at any other place than Greenwich, enter the Table with the longitude of the given place at the top, and the day of the month in one of the ſide columns, againſt which, and under the longitude, ſtands the correction of the ſun's declination on that account.

If the declination be wanted at any other place than Greenwich, and at any other time but noon, both corrections muſt be applied; and they muſt be added to, or ſubtracted from, the declination for noon at Greenwich, according to the directions which ſtand at the top of the column where the day of the month is found.

EXAMPLE I.

Find the ſun's declination for 21^{h} 17′ apparent time at Greenwich, May 4th, 1793.

May 4th, at 21^{h} 17′ is 2^{h} 43′ before noon on the 5th.
Sun's declination for noon, May 5th, 16° 27′ 34″ N.
2^{h} 43′ before noon gives .... — 1 59

Sun's declination, May 4th, at 21^{h} 17′ = 16 25 35 N.

EXAMPLE II.

What was the ſun's declination on the 19th of Auguſt, 1793, at noon, in longitude 97° weſt?

Sun's declination Auguſt 19th, at noon ...	12°	34′	35″	N.
97° Weſt longitude in Table VI. give ...	—	5	30	
Sun's decl. Aug. 19, at noon, in long. 97° W.	12	29	5	N.

EXAMPLE III.

What was the ſun's declination on the 14th of October, 1793, at $7^h 34'$ in longitude 83° eaſt?

Sun's declination October 14, at noon	8°	25′	26″	S.
$7^h 34'$ afternoon in Table VI. give	+	6	54	
83° Eaſt longitude in Table VI. give	—	5	3	
Sun's declination at $7^h 34'$ in long. 83° eaſt	8	27	17	S

PROBLEM IV.

27. To find the mean time at any place, the latitude and longitude of that place; or the latitude, and time at Greenwich, being given.

RULE.

Let ſeveral altitudes of the ſun's lower limb be obſerved when it is, at leaſt, three or four points of the compaſs from the meridian: Add theſe altitudes together, and divide the ſum by the number which were taken, and the quotient will be the mean obſerved altitude.

From the obſerved altitude of the ſun's lower limb, ſubtract the dip of the horizon, (Table II. of the Requiſite Tables) and the refraction (Table I.) and add the ſun's ſemidiameter, (page III. of the Nautical Almanac), and the parallax in altitude (Tab. III.) to the remainder; the ſum will be the true altitude of the ſun's center.

Take the ſun's declination from page II. of the Nautical Almanac by Problem III.

If the ſun's declination and the colatitude of the ſhip be one north and the other ſouth, take their difference; but if they be both north, or both South, take their ſum for the ſun's meridional altitude. If that ſum be greater than 90° take it from 180°.

From the natural ſine of the ſun's meridional altitude (Table XVII.) take the natural ſine of the ſun's true altitude at the time of obſervation; find the logarithm of the remainder, to which add the logarithmic ſecant of the ſhip's latitude, and the logarithmic ſecant of the ſun's declination; their ſum, rejecting 20 from the index, muſt be ſought for in Table XVI. under log-riſing, and the time correſponding to it will be the apparent time from the neareſt noon: conſequently, if the obſervation be made in the morning, the time thus found muſt be taken from 24 hours, and the remainder will be the apparent time from the noon of the preceding day.

Take the equation of time from page II. of the Nautical Almanac by Problem I. and add it to, or ſubtract from the apparent time as its title directs, and it will give the mean time.

EXAMPLE I.

January the 3d, 1793, about 20^h 45′ latitude 16° 23′ north, longitude 115° eaſt, the following altitudes of the ſun's lower limb were obſerved: what was the true mean time; the height of the obſerver's eye being 20 feet?

ALT.	⊙'s	L.L.
27°	45′	
27	51	
28	1	
28	7	
28	10	
139	54	
27	58,	48
+	10,	24
28	9,	12

Sun's declin. Jan. 4th, noon		22°	39′	1″ S,
3^h 15′ before noon give ...	+			50
115° Eaſt longitude give	+		1	58
Sun's d. at $20^h \frac{3}{4}$ in l. 115° E.		22	41	49 S.
Sun's ſemidiameter			16	19
Sun's parallax in altitude ...				8
			16	27
Dip of the horizon 4′ 16″ Refraction 1 47			6	3
Correction ſun's altitude			10	24
Sun's true altitude.				

	90°				
Ship's latitude	16	23′	N. Secant		10. 01800
Co-latitude	73	37	N.		
Sun's declin.	22	42	S. Secant		10. 03502
Sun's merid. alt.	50	55	Nat. ſine	77623	
Sun's true obſ. alt.	28	9	Nat. ſine	47178	
			Diff. nat. ſines	30445	Log. 4. 48351
Time before noon the 4th,	3° 16′ 01″		Log-riſing		4. 53653
Appa. time, January 3d,	20 43 59				
Equation of time	+ 5 32				
Mean time	20 49 31				

EXAMPLE II.

February the 3d, 1793, about half-paſt two o'clock, latitude 15° 50′ S. longitude 162° E. the following altitudes of the ſun's lower limb were obſerved: what was the true mean time; the height of the obſerver's eye being 21 feet?

ALT. ☉'s L. L.		
	Sun's declin. Feb. 3d, at noon	16° 17′ 5″ S.
54° 30′ 30″	2^h 30′ afternoon, give	— 1 46
54 25 00	162°. Eaſt longitude, give	+ 7 36
54 14 00	Sun's dec. at 2^h 30′ in l. 162° E.	16 22 55 S.
54 03 00	Sun's ſemidiameter	16 16
53 57 00	Sun's parallax in altitude ..	5
53 49 00		16 21
324 58 30	Dip. of the horizon 4′ 22″ Refraction 0 41	5 3
54 09 45 + 11 18	Correction ſun's altitude	11 18
54 21 3	Sun's true altitude.	

	90°.		
Latitude	15 50 S.	Log-ſecant	10.01680
Co-latitude	74 10 S.		
Sun's declination	16 23 S.	Log-ſecant	10.01800
	90 33 180		
Sun's merid. alt.	89 27	Nat. ſine	99995
True obſerved alt.	54 21	Nat. ſine	81259
		18736	Log. 4.27268
Apparent time Feb. 3d,	2^h 28′ 37″		Log-riſing 4.30748
Equation of time ...	+ 14 18		
Mean time	2 42 55		

28. Having now ſhewn how to find the mean time at the place where the obſerver is ſituated, I ſhall proceed to ſhew how it may be found at Greenwich, or the firſt meridian.

If a watch, or time-keeper, be regulated to keep mean time, exactly, and be ſet to the mean time at the firſt meridian; it is manifeſt that ſuch watch will continue to ſhew the mean time at that meridian, as long as it continues to go at the ſame rate, whatever place it may be carried to: and, conſequently, if a watch, ſo regulated, be kept on board a ſhip, it will always ſhew the mean time at the firſt meridian. Hence, if the mean time be found at the ſhip, by the preceding problem, the difference between it and the time ſhewn by the watch, when the ſun's altitude was obſerved, being turned into degrees and minutes at the rate of 15° to an hour, will be the longitude of the place where the ſun's altitude was obſerved, by Art. 18.

29. It is not, however, abſolutely neceſſary that the watch ſhould either be ſet preciſely to mean time at the firſt meridian, or be regulated to keep exactly mean time; both of which might, perhaps, be difficult, or, at leaſt, tedious to effect. The only

thing which is abſolutely requiſite in a watch, to render it equal to the taſk of finding the longitude, is, that it will go uniformly at ſome rate; becauſe the rate which it does go at, as well as its deviation from mean time at the firſt meridian, may be readily found, as follows, and allowed for.

30. Strictly ſpeaking, the *rate of a watch* is the number of hours, minutes, and ſeconds, which its hands appear to have moved over on the dial-plate in the ſpace of a mean ſolar day; but it is cuſtomary to call the difference between this time and 24 hours the *rate of the watch*. If the time ſhewn by the watch in a mean ſolar day be more than 24 hours, 24 hours are taken from it, and the remainder is called the *rate of the watch*; which is marked +, ſignifying that the watch gains. If the time ſhewn by the watch in a mean ſolar day be leſs than 24 hours, that time is ſubtracted from 24 hours, and the remainder is called the *rate of the watch*; and is marked —, which ſignifies that the watch loſes. And this is the ſenſe which the term is to be underſtood in throughout this tract.

PROBLEM V.

31. To find the rate which a watch goes at; that is, how much it gains or loſes on mean time in a day, or 24 hours; and how much it is too faſt, or too ſlow, for mean time at any place.

RULE.

The rate which a watch goes at may be found very readily, and with tolerable exactneſs, without the uſe of any inſtrument but Hadley's quadrant, or any obſervations but that of the ſun's altitude, which every ſeaman is, neceſſarily accuſtomed to make.

Sometime before the watch is wanted, a month may be ſufficient in moſt caſes, obſerve ſeveral altitudes of the ſun's lower limb, when it is, at leaſt, four points of the compaſs from the meridian, and note the times when they were obſerved by the watch.

Add theſe altitudes together, divide the ſum by the number of obſervations, and the quotient will be the mean altitude of the ſun's limb. Take, in like manner, the mean of the times by the watch.

Correct the mean obſerved altitude for the dip of the horizon, refraction, the ſun's ſemidiameter, and its parallax in altitude; and, with the altitude ſo corrected, the latitude of the place, and the ſun's declination find the mean time by Problem IV.

Take the difference between the mean time, and the mean of the times ſhewn by the watch, when the obſervations were made, and it will be what the watch was too faſt or too ſlow for mean time.

Immediately before the ſhip ſails, repeat theſe obſervations; and find again how much the watch is too faſt or too ſlow for mean time. Take the difference between the mean time of the firſt obſervation, and the mean time of the ſecond; alſo the difference between what the watch was too faſt, or too ſlow, at theſe two times; and the latter difference will be the loſs or gain of the watch, in the interval between the obſervations. Then, as the interval between the obſervations is to one day, ſo is the loſs or gain of the watch, between the obſervations, to its loſs or gain in one day.

EXAMPLE.

March 27th, 1793, the following obſervations were made on board a ſhip, lying in the Downs, latitude 51° 13′ N. and long. 1° 27′ E. for determining the rate which a watch went at, the height of the obſerver's eye being 22 feet.

Times by the watch.	Alt. of the Sun's L.L.
19ʰ 0′ 52″	11° 13′ 30″
1 26	19
1 50	25 30
2 21	31 15
2 44	37
9 13	126 15
19 1 50, 6	11 25 15
	+ 7 7
	11 32 22

Time at the ſhip . . .	19^h	2′
Longit. in time eaſt		6
Time at Greenwich	18	56
The ſun's ſemi-diameter	16′	4″
The ſun's parallax in alt.		9
	16	13
Dip of the hor. 4′ 28″ Refraction 4 38	9	6
Correction of the ⊙'s. alt.	7	7
Sun's true altitude.		

3° 17′ 5″ N. ſun's declin. noon, on the 28th.
— 4 56 Correction for 5^h 4′ before noon.

Sun's declin.	3 12 9	N. Secant	10. 00068
Co-latitude	38 47	N. Co-ſecant	10. 20316
Merid. Altit.	41 59 9	N. S. 66894 } 46890	Log. 4. 67108
True Altit.	11 32 22	N. S. 20004 }	
	5^h 2′ 2″,0	Log-riſing	4. 87492
	24		

Apparent time	18	57	58,0
Equation of time . .	+	5	04,0
Mean time	19	3	02,0
Time by the watch	19	1	50,6
Watch too ſlow. . . .		1	11,4

32. Again, May 3d, 1793, the ſhip being ready to ſail, the following obſerva-

tions were made: the error of the quadrant being 1′ 53″ to be added.

Times by the watch.	Alt. of the Sun's L. L.		
		Time at the ſhip . . .	18^{h}23′
		Longitude in time . .	6
		Time at Greenwich	18 17
18^{h} 21′ 37″	16° 16′ 45″		
22 13	22	Sun's ſemidiameter	15′ 54″
22 44	26 30	Parallax in altitude	8
23 17	31 45	Error of the quadrant	1 53
23 50	37 15		
			17 55
13 41	134 15	Dip of the hor. 4′ 28″ Refraction 3 12	7 40
18 22 44, 2	16 26 51		
	+ 10 15	Correction ſun's altitude	10 15
	16 37 6	Sun's true altitude.	

16° 10′ 31″ N. ſun's de. noon at Greenwich.
— 4 07 Correction for 5^{h} 43′ bef. noon.

Sun's declin. 16 6 24 N. Secant 10.01739
Co-latitude 38 47 00 N. Co-ſecant 10.20316

Meridian altit. 54 53 24 N.S. 81805 }
True altitude 16 37 6 N.S. 28600 } 53205 Log. 4. 72595

5^{h} 33′ 22″,6 Log-riſing 4. 94650
24

Apparent time 18 26 37, 4
Equation of time . . . — 3 29, 6

Mean time 18 23 7, 8
Time by watch 18 22 44, 2

Watch too ſlow . . . . 0 23, 6 at 18^{h} 23′ 8″ m. T.
Watch too ſlow March 27th 1 11, 4 at 19 3 02 m. T.

Watch has gained . . . . 0 47, 8 in 36^{d} 23 20 6, or 1″,293 in a day.

33. To obtain the rate which the watch goes at with greater certainty, obſervations may be made on more days than one, both at the beginning and end of the interval: or more than one ſet of obſervations may be taken on the ſame day, if opportunities offer, and the reſult of each ſet of obſervations, made at the beginning of the interval, muſt be compared with the reſult of each of thoſe taken at the end of it; by which means ſeveral daily rates will be obtained, which may differ a little one from another. In this caſe, the mean of them all muſt be taken for the true rate which the watch goes at.

34. Obſervations made only at the beginning and end of the interval, give the rate of the watch, on a ſuppoſition that it does not alter its rate of going in the time which elapſes between them; for if it does, thoſe obſervations will not detect it. It will therefore be prudent to take obſervations as often as circumſtances will permit, and find the rate which the watch has gone at between every two obſervations.

35. I have given this method of finding the rate which a watch goes at, becauſe it may be put in practice by every ſeaman, without introducing the uſe of any

inſtrument, or obſervation, which he is not already neceſſarily acquainted with; and becauſe it admits of being executed, if care and ſkill be exerted, with tolerable exactneſs: ſufficient, at leaſt, for the uſual length of a Weſt-India voyage, out, or home. It however, requires a very good inſtrument, and care and ſkill in the uſe of it: moreover, the utmoſt exactneſs muſt be obſerved in the calculations; and, when the utmoſt ſkill in both is exerted, it is not ſufficient for long voyages.

36. The moſt exact way of finding the rate which a watch goes at, and that which requires the leaſt calculation, is the method practiſed in fixed obſervatories, where they have tranſit inſtruments adjuſted to, and moving in the meridian of the place. This method has been lately adopted by ſome gentlemen*, in the Eaſt-India Company's ſervice, who have carried out portable tranſit inſtruments, for the purpoſe of examining their watches in India, before they ſet out on their voyage home.

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* It was Joſeph Huddart, Eſq. F. R. S. an Elder Brother of the Trinity-Houſe, and lately Commander of the Royal Admiral Eaſt-Indiaman, a very ingenious aſtronomer and mechanic, who, I believe, introduced this buſineſs into the ſervice.

DESCRIPTION AND USE OF THE TRANSIT INSTRUMENT.

37. A tranſit inſtrument is a teleſcope, of any convenient length, fixed at right angles to an horizontal axis; on which it turns in the plane of the meridian, or any other vertical circle.

Let F E (*fig.* 2,) repreſent an horizontal axis, the two ends of which, F and E, are perfect cylinders, and reſt on the frame, or ſupport, A B C D, in the angular notches A and D. The frame A B C D may be of caſt-iron; but the notches, or Y s, A and D, muſt be of bell-metal, and ſlide in grooves, which are ſcrewed firmly to the two upper ends of the iron frame. That at A has a vertical motion, governed by the ſcrew *h*, by which the end F, of the axis E F, is raiſed, or lowered, to bring the axis horizontal. The Y at D has an horizontal motion, governed by the ſcrew *g*, to bring the teleſcope to any mark the obſerver may wiſh to place it to; or to reſtore it to that mark if it be found, at any time, to deviate from it. Theſe Y s, or notches, with the apparatus which governs them, are repreſented more diſtinctly in *fig.* 3 and 4, where S repreſents that which has the vertical motion at A; and T that which has the horizontal motion at D. F and E are ſections of the axis, E F, reſting in them.

38. The axis E F (excluſive of the two cylindric pivots, E and F,) is formed of two hollow conic fruſtums of braſs, or tin; the two greater baſes meeting at W, where they are croſſed, at right angles, by two other hollow conic fruſtums, W G, W H, through which the teleſcope M N paſſes; the apertures at G and H being ſomewhat wider than is neceſſary to receive it. To fix the teleſcope in its place, there are four ſmall ſcrews, two at the aperture G and two at H. Thoſe at G (toward the eye-end of the teleſcope) act one againſt the other, in an horizontal direction; one of them appears at *b*, and the other is diametrically oppoſite to it, and, conſequently, hid by the teleſcope. The two ſcrews which are at H, (one of which appears at *c*) act one againſt the other in a vertical poſition. Theſe ſcrews have fine conical points; ſo that when they are forced againſt the tube of the teleſcope, they will form ſmall conical holes in it for themſelves to reſt in.

39. Five very fine ſilver wires are placed in the common focus of the two glaſſes of the teleſcope, exactly parallel to, and equidiſtant from each other: the middle one biſecting as nearly as the inſtrument-maker can poſſibly make it, the field of the teleſcope; and a ſixth wire is placed at right angles to theſe, biſecting alſo the field of the teleſcope. This ſyſtem of wires is repreſented in *fig.* 5, and requires no farther explanation.

40. OPQR is a ſpirit level, which being hung on the two cylindric ends of the axis F and E, by means of the angular hooks, O and R, the end F, of the axis, is raiſed or lowered by the ſcrew *h*, until the level ſhews that the axis is horizontal.

41. LZKI is a ſemicircle, divided into two quadrants of 90 degrees each, beginning at L and I, and meeting in Z, at 90°. EK is an index, twiſted on to the end E of the axis, having a Vernier's diviſion at K, which ſubdivides the arch to every 3′; and which is ſet to 90°, at Z, when the teleſcope points to the zenith. By means of this arch and index the teleſcope may be ſet with preciſion, to the meridional altitude of any object, the paſſage of which,

over the meridan, is required to be obſerved; whether it paſſes to the northward or ſouthward of the zenith.

42. The cylindric pivot F is perforated, and ſo alſo is that ſide of the tube of the teleſcope, which is oppoſite to it; and within the tube, and directly oppoſite this perforation, a plane reflector is fixed, at an angle of 45° with the axis of the teleſcope, having a hole through it, large enough to admit all the rays paſſing from the object glaſs of the teleſcope.

43. When ſtars are obſerved in the night, a ſmall candle, in a ſtick which has a contrivance for ſetting the candle higher or lower, is placed oppoſite the hole in the pivot, the light of which falling on the reflector in the tube of the teleſcope, is thrown by it on the wires in the focus of the teleſcope; by which means they are rendered viſible to the obſerver. By placing the candle nearer to, or farther from the end of the pivot F, the quantity of light thrown on the wires may be regulated to the wiſh of the obſerver.

TO LEVEL THE AXIS.

44. Hang the level on the axis, the hook O on the pivot F, and the hook R

on the pivot E, and raiſe or lower the end F, by the ſcrew *h*, until the bubble reſts exactly in the middle of the glaſs tube. This being done, invert the level, hanging the hook O on the pivot E, and the hook R on the pivot F. If the bubble ſtill reſt in the middle of the tube, the axis of the inſtrument is parallel to the horizon. But if the bubble do not now reſt exactly in the middle of the glaſs tube of the level, turn the ſmall ſcrew *q*, which is at the end Q of the level, until you have moved the bubble half-way toward the middle of the tube, and carry it the other half by turning the ſcrew *h*. Invert the level again, hanging the hook O on the pivot F, and the hook R on the pivot E; and if you were exact in eſtimating half the error of the level, the bubble will now reſt exactly in the middle of the tube, and the axis will be level. But if it be not, correct half the error by the ſcrew *q*, and the other half by the ſcrew *h*, and invert the level until the bubble will reſt exactly in the middle of the tube, when the level is hung on both ways.

TO FIX THE TELESCOPE AT RIGHT ANGLES TO THE AXIS.

45. Let the ſcrews at G and H be withdrawn till their points be barely even with the internal ſurfaces of the two conical arms W G, W H, lay the axis in the Y *s*, and place it truly horizontal by means of the level. Turn the axis in the Y *s* until the two arms W G, W H, are alſo in an horizontal poſition, paſs the teleſcope through theſe arms until it be exactly in equilibrio on the axis, and then let it reſt freely in the arms with the five parallel wires, as nearly perpendicular to the horizon as you can place them by your eye. Turn the frame which carries the inſtrument round on the ſcrew-pin U, until the middle wire, of the five parallel ones, be on ſome diſtant, well-defined object, and turn the teleſcope a little on the axis E F, noting at the ſame time, whether the middle wire remains conſtantly on the mark throughout the whole extent of the field of the teleſcope. If it does not, the teleſcope muſt be turned in the arms W G, W H, until the middle vertical wire will remain exactly on the mark, when the inſtrument is turned on the axis E F, through-

out the whole extent of the field. Turn now the ſcrew *c*, till its point preſſes the tube of the teleſcope, as it lies in the arms W G, W H; taking care that the teleſcope ſtill remains in the ſame poſition, and that the middle wire will remain exactly on the mark throughout the whole extent of the field of the teleſcope, at the ſame time that the axis F E is ſhewn by the level to be parallel to the horizon. Being well aſſured of theſe two points, turn the ſcrew *c*, till its point, by preſſing againſt the tube of the teleſcope, forms a ſmall conical impreſſion in it; and this being done, turn the ſcrew which is oppoſite to *c*, till its point alſo make a ſmall impreſſion in the tube of the teleſcope; after which the ſcrew *c* may be eaſed, ſcrewing up the oppoſite one at the ſame time, till the teleſcope is brought into the center of the aperture at H. And it is plain, that if the wires have been kept, during this operation, perpendicular to the horizon, they muſt remain ſo, as long as the ſcrews are kept tight, becauſe the teleſcope can have no power to turn round. Raiſe the end M of the teleſcope, in the aperture G, by putting ſlips of paper under it, until it be in the center of the aperture: then turn the ſcrew *b*, and its oppoſite one, until their points preſs againſt, and form ſmall conical holes in the tube of the teleſcope. By turning the ſcrew *g*, bring the middle wire, of the five vertical ones, very exactly on to the mark which was uſed in ſetting it perpendicular to the horizon, or on to any other which is ſmall, and perfectly diſtinct: then turn the axis end for end; that is, turn the pivot E into the notch A, and the pivot F into the notch D; and if the middle vertical wire be ſtill exactly on the mark, the line of collimation of the teleſcope is perpendicular to the axis FE. If the middle wire be not on the mark when the axis has been inverted, bring the wire half way toward the mark by eaſing one of the ſcrews at *b*, and ſcrewing up the other; and then bring the wire exactly on to the mark by the ſcrew *g*. Invert the axis EF again; that is, bring the end F into the notch A, and the end E into the notch D; and, if you were exact in eſtimating half the diſtance which the wire deviated from the mark, it muſt now be exactly on it. If it be not, bring the wire half way toward the mark by the ſcrews at *b*, and the other half by the ſcrew *g*; and try, again, by inverting the axis, whether you have now done it right; if you have not, the operation muſt be repeated until the middle wire be exactly on the mark, which ever end of the axis FE is in the notch A.

TO ADJUST THE TELESCOPE.

46. That is, to place the eye-glaſs and object glaſs at ſuch a diſtance from each other, that their reſpective *foci* may co-incide: after which the wires are to be brought into their common focus. To effect this, ſome teleſcopes have the eye-glaſs and cell which carries the wires moveable, while the object-glaſs is fixed: others have the wires fixed and the two glaſſes moveable. In the former caſe, by puſhing in, or drawing out the eye-piece, adjuſt the teleſcope ſo that the ſun or a planet appears perfectly diſtinct through it; then move the wires nearer to, or farther from the eye-glaſs, as may be required, until they alſo appear perfectly diſtinct, and the teleſcope will be adjuſted ready for uſe. In the latter conſtruction, puſh in, or draw out the eye-piece till the wires appear perfectly diſtinct, then alter the object-glaſs until the ſun, or a planet, appear perfectly diſtinct alſo, and

the teleſcope will be adjuſted ready for uſe.

47. As it is of importance to have the teleſcope adjuſted very exactly in this reſpect, the following method of trying whether it be ſo or not, may be practiſed.

The teleſcope being adjuſted to diſtinct viſion for diſtant objects, when a fixed ſtar is on the meridian, bring the horizontal wire to biſect it very exactly, and the ſtar will run along the wire through the whole extent of the field of the teleſcope. While the ſtar is thus running along the wire, move your eye a little upward or downward; and, if the wires be not exactly in the common focus of the two glaſſes, the ſtar will appear to quit the wire when the eye is moved. If this be the caſe, the wires, or glaſſes, muſt be altered until the ſtar will not quit the wire when the eye is moved; the objects appearing perfectly diſtinct at the ſame time.

TO OBSERVE THE PASSAGE OF A STAR OVER THE MERIDIAN BY A TRANSIT INSTRUMENT.

48. From the latitude of the place and the ſtar's declination find its meridional al-

titude *; and a little before the time when it will be on the meridian †, ſet the teleſcope to this altitude, by means of the ſemi-circle L Z I, and index E K. Apply your eye to the teleſcope, and wait till you ſee the ſtar come into it, which will be (apparently) on the weſt ſide, becauſe the teleſcope inverts objects. Let your aſſiſtant attend to the watch, and at the inſtant when the ſtar is on the firſt wire, bid him *mark* the ſecond, and parts of a ſecond, when it happened; which he muſt ſet down on a paper, ready ruled for that purpoſe, and then attend again to the watch. When the ſtar is on the ſecond wire, bid him *mark* the ſecond, &c. when it happened, as before; which being written down, with the minute, proceed to obſerve the inſtants when the ſtar is on every one of the other wires; after which the proper hour may be annexed.

An aſſiſtant is not neceſſary when the time is taken by a clock, the beats of which can be diſtinctly heard by the obſerver: indeed, the obſervation may be made more exactly without one. When a clock is uſed, the obſerver, catches the ſecond from the clock by his eye, which he then applies to the teleſcope, telling the ſeconds on by his ear until he ſees the ſtar on the wire. He then writes down the ſecond and parts of a ſecond when it happened, and prefixes the minute; after which, he catches the ſecond from the clock again by his eye, and tells on by his ear until the ſtar arrives at the ſecond wire, and ſo on.

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* If the latitude and declination be both north, or both ſouth, add the co-latitude to the ſtar's declination: but if one be north and the other ſouth, take their difference.

† This may be found by ſubtracting the ſun's right aſcenſion for the day, (Nautical Almanac, p. II.) from the ſtar's right aſcenſion, (Requiſite Tables, Tab. VII.)

TO BRING A TRANSIT INSTRUMENT INTO THE MERIDIAN.

49. Take altitudes of the ſun, noting the times by the watch when they were taken: and, from thence, the latitude of the place, and the ſun's declination, find the *apparent* time by Art. 27. The difference between this time, and the mean of the times ſhewn by the watch when the obſervations were made, will be what the watch is too faſt, or too ſlow, for *apparent* time.

If the watch be too faſt, add what it is too faſt to 12 hours: but if it be too ſlow, ſubtract what it is too ſlow from 12 hours, and you will have the time by the watch, when the ſun will be on the meridian, as near as the going of the watch can be depended on. Take the time which the ſun's ſemidiameter is paſſing the meridian from page III. of the Nautical Almanac, and add it to, and ſubtract it from the time by the watch, when the ſun will be on the meridian, and you will have the times when the ſun's eaſtern and weſtern limbs will be on the meridian.

A few minutes before the time when the weſtern limb will be on the meridian, bid your aſſiſtant tell the ſeconds, as they paſs, by the watch; but inſtead of calling the 60th ſecond, let him name the minute the watch is then at. While he is doing this you muſt bring the ſun into the teleſcope by elevating it to the proper altitude; and turning the whole inſtrument round on the ſcrew-pin U. Having, by this means brought the middle wire apparently to the eaſtward of what appears to be the eaſtern limb of the ſun, (becauſe the ſun will appear to move that way in the teleſcope) tighten the ſcrew U by turning the nut; and when the ſun's limb arrives at the middle wire, keep it on it by turning the ſcrew *g*, at the rate the ſun moves, till your aſſiſtant calls the ſecond by the watch at which you had computed the weſtern limb of the ſun would be on the meridian, and the inſtrument will be nearly in the meridian. Let your aſſiſtant tell on till the watch arrives at the ſecond when, according to your calculation, the eaſtern limb of the ſun ſhould be on the meridian; and, if it is not exactly on it, you will have another opportunity of rectifying the inſtrument by turning the ſcrew *g*.

50. On this, and ſeveral other occaſions, if you have not a darkening-glaſs fitted to the eye-end of the teleſcope, it will be convenient to have a pair of ſpectacles with plane dark-glaſſes, of different degrees of darkneſs, inſtead of lens.

51. Having thus brought the inſtrument into, or very near the meridian, its real ſituation, with reſpect to the meridian, may be verified ſeveral ways; of which I ſhall point out two. If the latitude of the place be conſiderable; that is, 30 degrees, or upward, there are a variety of ſtars in both hemiſpheres, ſufficiently bright, which never ſet; and, conſequently, may be obſerved at the inſtrument both above and below the pole. Let the tranſits of ſuch a ſtar over the meridian be obſerved above the pole, below the pole, and above the pole again: and it is manifeſt that if the

time of the firſt tranſit above the pole, be ſubtracted from the time of the ſecond tranſit above the pole, (adding 24 hours, if neceſſary) the remainder will be the time by the watch, in which the earth (or the ſtar apparently) makes one diurnal revolution. It is alſo evident, that if the two intervals between the time of the tranſit below the pole, and the two tranſits above the pole be equal, the inſtrument muſt be exactly in the meridian. If the interval between the firſt tranſit above the pole, and the tranſit below the pole, be greater than the interval between the tranſit below the pole, and the ſecond tranſit above it, the object end of the teleſcope, when directed toward the elevated pole, lies to the eaſt of the true meridian; but if the latter interval be greateſt, the object end of the teleſcope, when directed toward the elevated pole, lies weſt of the true meridian. To correct the error, and bring the inſtrument into the meridian, add 24 hours to the time of the latter tranſit above the pole, ſubtract the time of the former from it, and take half the remainder. Take the difference between this and the interval between the tranſits above and below the pole, and take half this difference. Then as the time by the watch of an entire revolution is to 24 hours, ſo is this half difference to the half difference in ſiderial time. Add together the logarithm of this half-difference, the logarithmic tangent of the ſtar's polar diſtance; and the logarithmic ſecant of the latitude of the place, the ſum, rejecting 20 from the index, will be the logarithm of the number of ſeconds *in time*, which expreſſes the angle made by the inſtrument and the meridian.

Conſider what part this angle makes of the interval, between the wires which are in the focus of the teleſcope*: and turn the inſtrument, on its axis, till the teleſcope points to the horizon. Look out for ſome tolerably diſtinct object which is cut by one of the wires; and, by turning the ſcrew *g*, remove the wire to the eaſt or weſt of this object, (as may be required) ſuch a part of the ſpace between that wire and the next to it, as the angular error of the inſtrument makes of that interval. You muſt then proceed to examine the poſition of the inſtrument again, either by the ſame, or ſome other circum-polar ſtar, and to correct it, if it requires correction, until you get it exactly into the plane of the meridian: and when you have, a mark muſt be ſet up in the meridian, at as great a diſtance from the inſtrument as may be convenient, or as it can be ſeen diſtinctly; and the teleſcope muſt be carefully adjuſted to this mark before every obſervation.

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* The interval between the wires in the focus of the teleſcope may be found by obſerving the tranſits of one, or more of the ſtars δ Ceti, δ Orionis, υ Leonis, η or γ Virginis, η Antinoi, λ Aquarii, κ or λ Piſcium, or any other ſtar which is very near the equator.

EXAMPLE.

52. Admit that Capella paſſed the tranſit inſtrument, at Greenwich, September 6th, 1794, above the pole at $17^{h}\ 59'\ 11'',5$, below the pole at $5^{h}\ 57'\ 5'',6$, and above the pole, again, at $17^{h}\ 55'\ 21'',0$: how much did the inſtrument deviate from the meridian, and which way?

The difference between the times of the firſt tranſit above the pole and the ſecond is $23^{h}\ 56'\ 9'',5$; half of which is $11^{h}\ 58'\ 4'',75$. The difference between the times of the firſt tranſit above the pole and the tranſit below it, is $11^{h}\ 57'\ 54'',1$; which is leſs than the time of half a revolution by $10'',65$; and half of this is $5'',325$. Hence, the object-end of the teleſcope, when directed toward the elevated pole was weſt of the meridian. As 23^h 56′ 9″,5 (the time of a revolution of the fixed ſtars by the watch) is to 24 hours, ſo is 5″,325 to 5″,34. And as the tangent 45° 46′ 25″, the ſtar's declination, is to the ſecant of 51° 28′ 40″, the latitude of the place, ſo is 5″,34 to 8″345, the angle under which the inſtrument cuts the plane of the meridian, in time.

53. To adjuſt the inſtrument to the plane of the meridian, let us ſuppoſe that a ſtar at the equator had been obſerved, and found to take up 36″½ in paſſing from wire to wire, 8″,345 is about two-ninth parts of this quantity, or ſomewhat more than one-fourth. Bring the teleſcope to the horizon, and look out for ſome diſtinct object which is cut by one of the wires; then, by turning the ſcrew *g*, remove the teleſcope until the object which was on the wire, appears to be about two-ninths, or nearly one-fourth of the diſtance between that wire and the next to it toward the right hand: if the inſtrument had been eaſt of the meridian, the ſcrew *g* muſt have been turned till the object appeared to be removed, the like quantity toward the left-hand. In conſidering the propriety of theſe inſtructions, the reader muſt re-

member that the teleſcope inverts objects.

54. This is the beſt practical method that I know, for placing a tranſit inſtrument in the meridian, when it can be uſed: but if the place of obſervation be very near the equator; or, if any local impediment prevent you from obſerving circum-polar ſtars above and below the pole, the following one, given by the Rev. Dr. Maſkelyne, Aſtronomer Royal, in the Philoſophical Tranſactions for 1775, Vol. LXV. may be uſed. But before this can be done it will be neceſſary to ſhew how to find the deviation of a fixed ſtar in right aſcenſion in time.

55. Take the ſtar's right aſcenſion in time, and its declination, from Table IV. for the time when it is wanted.

Turn the right aſcenſion in time into motion by allowing one ſign for every two hours, 15 degrees for one hour, one degree for every four minutes, and one minute for every four ſeconds of time.

Enter Table V.* with the ſtar's right aſcenſion, and take out the degrees and minutes correſponding to it, and alſo the logarithm.

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* This Table is Table VI. in Dr. Maſkelyne's collection, adapted to the purpoſe under conſideration.

Add the degrees, &c. taken out of Table V. to, or ſubtract them from the ſtar's right aſcenſion as the ſigns + or — direct; and take the difference between the right aſcenſion, ſo corrected, and the longitude of the moon's aſcending node, (Nautical Almanac, p. III.) ſo that the remainder may be leſs than ſix ſigns, or 180 degrees.

To the logarithmic co-ſine of this remainder add the logarithm taken out of Table V. and the logarithmic tangent of the ſtar's declination: their ſum, rejecting all the tens in the index, will be the logarithm of the ſtar's deviation in decimal parts of a ſecond. To be added to the right aſcenſion in time of a northern ſtar, when the difference between the ſtar's corrected right aſcenſion and the longitude of the moon's node is greater than 3 ſigns, or 90°; but it muſt be ſubtracted from it when that difference is leſs than 3 ſigns. If the ſtar have ſouth declination, the deviation muſt be ſubtracted from the right aſcenſion, when the difference between the ſtar's corrected right aſcenſion and the longitude of the moon's node is greater than 3 ſigns, and added to it when that difference is leſs than 3 ſigns.

EXAMPLE I.

What is the deviation of Fomalhaut, September 28th, 1796?

Star's Æ at the time $22^h 46' 24'' =$	$11^s 11° 36'$	
Correction from Table V.	+ 4 30	
Star's corrected right aſcenſion	11 16 06	
Long. ☽'s node (Naut. Alm. p. III.)	15 6 13	
Difference	3 20 07	coſ. 9. 536
Logarithm from Table V.		9. 795
Star's declination ſouth		tang. 9. 774
Fomalhaut's deviation	ſubt. 0″,13	log. 9. 105

EXAMPLE II.

What is the deviation of β Pegaſi, September 28th, 1796?

Star's Æ at the time $22^h 53' 56'' =$	$11^s 13° 29''$	
Correction from Table V.	+ 4 4	
Star's corrected right aſcenſion	11 17 33	
Long. ☽'s node (Naut. Alm. p. III.)	15 6 13	
Difference	3 18 40	coſ. 9. 505
Logarithm from Table V.		9. 797
Star's declination north		tang. 9. 707
Deviation of α Pegaſi	0″,1	log. 9. 009

56. Dr. Maſkelyne's method is general, but to avoid ſome parts of the calculation

which ſeamen, in general, are not accuſtomed to, I ſhall give it with certain limitations.

Chuſe two ſtars which have nearly the ſame right aſcenſion: let their declinations alſo be nearly equal, neither of them leſs than 25 or 30 degrees; but let one be north, and the other ſouth, ſo that their difference in declination may not be leſs than 50 or 60 degrees. Moreover, let them not paſs the meridian before 9 o'clock, nor after three. Obſerve the tranſit of each of them twice by the inſtrument; from which you will obtain the time ſhewn by the watch during a revolution of the fixed ſtars, and alſo between the tranſits of the two ſtars over the inſtrument. Reduce the time elapſed between the tranſits of the two ſtars, according to the watch, to parts of the equator, and it will be the obſerved difference of their right aſcenſions. Take the right aſcenſions and declinations of the two ſtars from Table IV. for the time of the obſervation, correct their right aſcenſions for deviation*, by Art. 55, and take the difference of the right aſcenſions, ſo corrected; and if this difference be equal to the obſerved difference of their right aſcenſions, the inſtrument is truly in the meridian. If the obſerved difference of their right aſcenſions be greater than the true, and that ſtar paſs firſt which is neareſt the elevated pole; or, if the obſerved difference of right aſcenſion be leſs than the true, and the ſtar neareſt the elevated pole paſs laſt, that end of the teleſcope which is directed toward the elevated pole is eaſt of the meridian. If the obſerved difference of right aſcenſion be leſs than the true, and the ſtar neareſt the elevated pole paſs firſt; or if the obſerved difference of right aſcenſion be greater than the true, and the ſtar neareſt the elevated pole paſs laſt, that end of the teleſcope which is directed toward the elevated pole is weſt of the meridian.

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* The mean places of the ſtars are exhibited in the tables; and to obtain their apparent places, which are thoſe obſerved, the mean places muſt be corrected for aberration, and the equation of the equinoctial points, as well as for deviation: but as

57. Having thus found which way the inſtrument deviates from the meridian, the

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it is only the difference between the apparent right aſcenſions of the two ſtars which is wanted here, and not the right aſcenſions themſelves; and, as the equation of the equinoctial points affects the right aſcenſions of all ſtars alike, and the ſtars in Table IV. are ſo ſelected that each pair is equally affected by aberration, or nearly ſo; it will not be neceſſary to apply theſe two corrections.

quantity of the deviation may be found as follows:

Add the declinations of the two ſtars together, (one being north and the other ſouth) and the ſum will be the difference of their declinations.

Take the difference between the obſerved difference of the right aſcenſions of the two ſtars, and the apparent difference of their right aſcenſions; to the logarithm of which (in ſeconds) add the log. co-ſines of their declinations, the log. co-ſecant of the difference of their declinations, and the log. ſecant of the latitude of the place of obſervation: their ſum, rejecting 40 in the index, will be the logarithm of the number of ſeconds *in time*, which expreſſes the angle made by the inſtrument and the meridian. This being done, the inſtrument may be brought into the plane of the meridian by the inſtructions given in Art. 53.

EXAMPLE.

Suppoſe that at Barbadoes, latitude 13° 5′ N. the ſtar Fomalhaut, paſſed a tranſit inſtrument at 10^h 24′ 12″,4 by a watch, on the 28th of September, 1796, and that at 10^h 32′ 1″,8 α Pegaſi paſſed the ſame inſtrument; ſuppoſe alſo, that on the 29th, Fomalhaut paſſed the ſame inſtrument at $10^{h}\ 20'\ 22''$ and α Pegaſi at $10^{h}\ 28'\ 11'',2$: How much did that inſtrument deviate from the meridian, and which way?

Æ of Fomal. Tab. V.	$22^{h}\ 46'\ 16'',6$	of β Peg.	$22^{h}\ 53'\ 51'',2$
Annual variation .. +	3, 32		2, 87
Three fourths d°. ...	2, 48		2, 16
Mean Æ Sept. 1796,	22 46 22, 4		22 53 56, 2
Deviation (Art. 55.)	— 1		+ 1
	22 46 22, 3		22 53 56, 3
			22 46 22, 3
Apparent difference of right-aſcenſion			0 7 34, 0
	24^{h}		24^{h}
Fom. paſſ. on the 29th	$10\ 20'\ 22'',0$	β Peg. at	10 28 11, 2
	34 20 22, 0		34 28 11, 2
Fom. paſſ. on the 28th	10 24 12, 4		10 32 1, 8
Time of a revolution	23 56 9, 6		23 56 9, 4
The m. of the two is	23 56 9, 5		
Fomalhaut paſſed before β Pegaſi on the 28th			$7'\ 49'',4$
on the 29th			7 49 ,2
Mean obſerved difference			7 49 ,3

As $23^{h}\ 56'\ 9'',5$ is to 24^{h} ſo is $7'\ 49'',3$ to $7'\ 50'',55$, the obſerved difference of right aſcenſion: the difference between this and $7'\ 34'',0$ is $16'',55$, the quantity by which the obſerved difference of right aſcenſion exceeds the apparent; and the ſtar neareſt the elevated pole paſſed laſt: conſequently, that end of the teleſcope which is directed toward the elevated pole lay weſt of the meridian.

58. To bring the inſtrument into, or nearer the meridian, let us ſuppoſe a ſtar at the equator, as before, was 36″½ paſſing from one wire to another. By Table IV. the declination of Fomalhaut, is 30° 41′ 36″ S. and the declination of β Pegaſi 26° 58′ 54″ N. their ſum, which is the difference of their declinations, is 57° 40′ 30″.

Error in Æ		16″, 55	Log.	1, 21880
Fomalhaut's declin.	30° 42′		co-ſine	9, 93442
β Pegaſi's declin.	26 59		co-ſine	9, 94995
Different declin.	57 41		co-ſec.	10, 07309
Lat. Barbadoes	13 5		ſecant	10, 01142
Error of the inſtru.		15″, 4	Log.	1, 18768

This is very near three-ſeventh parts of the interval between the wires in the focus of the teleſcope; and therefore, having found an object in the horizon which is cut by one of the wires, turn the ſcrew *g* until that object appears to be removed three-ſeventh parts of the ſpace, which is between the wire it was on before, and the next to it (apparently) toward your right hand, and the inſtrument will be in, or very near the meridian; and its real poſition may be examined by the ſame, or any other pair of ſtars, and adjuſted till you find it exactly in the meridian.

TO OBSERVE THE SUN'S TRANSIT OVER THE MERIDIAN.

59. From the latitude of the place and the ſun's declination find its meridional altitude by Note 1. Art. 48; and, a few minutes before noon, ſet the inſtrument to this altitude, by means of the ſemi-circle LZI and index EK. Apply your eye (defended by a dark glaſs) to the teleſcope, and wait till you ſee the firſt limb of the ſun enter it; which will be (apparently) on the weſt ſide, becauſe the teleſcope inverts objects. When this happens let your aſſiſtant attend to the watch; and, when the firſt limb of the ſun touches the firſt wire, bid him *mark* the ſecond, and parts of a ſecond, which are ſhewn by the watch; and which he muſt ſet down, in the firſt column of a paper that contains five, ready ruled for the purpoſe. He muſt then prefix the minute, and attend again to the watch. When the ſun's firſt limb arrives at the ſecond wire, bid him again *mark* the ſecond, and parts of a ſecond ſhewn by it; which being ſet down in the ſecond column of his

paper, and the minute prefixed, he muſt attend again to the watch. And in this manner the times when the ſun's firſt limb arrives at every one of the wires muſt be obſerved, and noted down in its proper column. The times when the ſecond limb arrives at each of the five wires muſt be obſerved in the ſame manner, and written in their proper columns, under thoſe of the firſt. If the wires in the focus of the teleſcope be ſo diſpoſed, that there is not time to obſerve the firſt limb at all the five wires before the ſecond limb arrives at the firſt wire, the obſervation of the firſt limb at the fifth wire muſt be omitted, and, in this caſe, the obſervation of the ſecond limb at the firſt wire may be omitted alſo, as it will be of no uſe.

60. The mean of the times when the two limbs of the ſun, were at the middle wire will be the time of apparent noon by the watch; and, if the wires are equidiſtant, (as they ought to be) the mean of the two times when the firſt limb was at the firſt wire, and the latter limb at the fifth wire will alſo be the time of noon. Alſo the mean of the two times when the firſt limb was at the ſecond wire, and when the latter limb was at the fourth wire will

be the time of noon; as alſo the mean of the times when the firſt limb was at the fourth wire and the latter limb at the ſecond. If the firſt limb was obſerved at the laſt wire, and the latter limb at the firſt, the mean of theſe two obſervations will alſo be the time of apparent noon; and the mean of all theſe reſults, if they differ, as they moſt likely will, is the time of apparent noon by the watch.

TO FIND THE RATE WHICH A WATCH GOES AT BY OBSERVATIONS OF THE SUN'S TRANSIT OVER THE MERIDIAN.

61. Obſerve the time when the ſun tranſits the meridian of the place, by Art. 59, every day at noon, or as often as opportunities offer. The equation of time muſt then be taken from the Nautical Almanac by Art. 24; and, if it be marked additive, it will be the ſame as the time by the watch when the ſun's center was obſerved to paſs the meridian, if the watch be right. If they differ, that difference is what the watch is too faſt, or too ſlow for mean time: and it is too faſt if the time by the watch be greater than the equation of time; and too ſlow if the time by the watch be leſs. If the equation of time be ſubtrac-

tive, take it from twenty-four hours, compare the obſerved time when the ſun's center was on the meridian with the remainder, and the difference between them will be what the watch is too faſt, or too ſlow, according as the time by the watch is the greater or the leſs. Theſe obſervations, when the voyage is expected to be of a conſiderable length, ought to be continued for a month, at leaſt: indeed, the longer they are continued, in all caſes, the better; but in this the obſerver muſt be governed by circumſtances. They muſt always, however, be continued as near as poſſible to the time when the ſhip is expected to ſail, that there may be as little chance as poſſible left for the watch to alter its rate of going after the obſervations are cloſed.

62. The times by the watch when the ſun's center was obſerved on the meridian, muſt be written one under another, againſt the days of the month when they were obſerved; and it is the day that began at the inſtant when the ſun's center was on the meridian which is to be ſet before the obſerved time; and not the day which ended then, as is the cuſtom with ſeamen. The equation of time, or its ſupplement to 24 hours, according as it is additive, or ſub-

tractive, muſt be ſet in another column, againſt the obſerved times of noon, and the difference between them in a third, with the ſign + or —, according as the watch is too faſt or too ſlow for mean time. This is all that is neceſſary to be done till all the obſervations are made.

63. When the ſhip is ready to ſail, add a fourth column to your paper, take the difference between what the watch was too faſt or too ſlow on the firſt day of obſervation, and what it was too faſt or too ſlow on the ſecond, and put it in the fourth column, oppoſite the ſpace which is between the two numbers of which it is the difference. Take alſo the difference between what the watch was too faſt or too ſlow on the ſecond day, and what it was too faſt or too ſlow on the third; between what it was too faſt or too ſlow on the third, and what it was too faſt or too ſlow on the fourth; and ſo on. Place theſe differences alſo in the fourth column, oppoſite the ſpaces which are between the two numbers of which they are, reſpectively, the difference. Thoſe differences will be the gain or loſs of the watch in the twenty-four hours, which they reſpectively ſtand againſt: And it muſt be obſerved, that the

watch is gaining if it be too faſt for mean time, and the numbers in the third column increaſe; or if it be too ſlow, and the numbers in the third column decreaſe: but the watch is loſing if it be too faſt for mean time, and the numbers in the third column decreaſe; or if it be too ſlow, and the numbers in the third column increaſe.

64. By making daily obſervations in the manner here recommended, it will be ſeen whether the watch alters its rate of going while it is under trial, which is abſolutely neceſſary to be known; becauſe, if it does, all thoſe obſervations muſt be rejected which were made before the alteration happened, and thoſe only retained which were made afterward.

65. If no material alteration happened in the rate of the watch's going, during the time of trial, take the difference between what the watch was too faſt or too ſlow on the firſt day of obſervation, and what it was too faſt or too ſlow on the laſt, if they be of the ſame kind; that is, both too faſt, or both too ſlow; but add them together if the watch was too faſt in one inſtance and too ſlow in the other; this difference, or ſum, muſt be divided by the number of days which elapſed between the firſt and

laſt day's obſervations, and the quotient will be the number of ſeconds and decimal parts that the watch gains or loſes in a day. And it is manifeſt, that if the watch be faſter at the end of the trial, than it was at the beginning, it is gaining; and if it be ſlower, it is loſing.

66. If any conſiderable alteration happened in the rate which the watch went at, inſtead of taking the difference between what the watch was too faſt, or too ſlow, on the firſt and laſt days, take the difference between what the watch was too faſt or too ſlow on the day after that, when the alteration in its rate happened, and what it was too faſt or too ſlow on the day when the laſt obſervation was made, and divide by the number of days which elapſed between them. The following example will make this very plain.

67. Suppoſe the obſerved times when the ſun's center paſſed the meridian of Barbadoes, in the month of December 1793, were as follow; what was the loſs or gain of the watch on mean time?

1793.		Obſ. Times of ☉'s Tran.	Mean Time of app. Noon.	Watch too faſt.	Daily gain.
		H. M. S.	H. M. S.	H. M. S.	S.
☉ Decem.	1	3 50 34,0	23 49 41,7	+ 4 0 52,3	
☽ - - -	2	3 51 2,1	23 50 5,4	+ 4 0 56,7	+ 4,4
♂ - - -	3	3 51 30,6	23 50 29,7	+ 4 1 0,9	+ 4,2
☿ - - -	4	3 51 59,2	23 50 54,6	+ 4 1 4,6	+ 3,7
♃ - - -	5	3 52 26,2	23 51 20,1	+ 4 1 6,1	+ 1,5
♀ - - -	6	3 52 54,0	23 51 46,1	+ 4 1 7,9	+ 1,8
♄ - - -	7	3 53 21,9	23 52 12,6	+ 4 1 9,3	+ 1,4
☉ - - -	8	3 53 50,3	23 52 39,5	+ 4 1 10,8	+ 1,5
☽ - - -	9	3 54 18,9	23 53 6,9	+ 4 1 12,0	+ 1,2
♂ - - -	10	3 54 47,7	23 53 34,6	+ 4 1 13,1	+ 1,1
☿ - - -	11	3 55 16,4	23 54 2,6	+ 4 1 13,8	+ 0,7
♃ - - -	12	3 55 46,7	23 54 31,0	+ 4 1 15,7	+ 1,9
♄ - - -	14	3 56 48,7	23 55 28,6	+ 4 1 20,1	+ 2,2
☉ - - -	15	3 57 19,8	23 55 57,7	+ 4 1 22,1	+ 2,0
☽ - - -	16	3 57 51,3	23 56 27,0	+ 4 1 24,3	+ 2,2
♂ - - -	17	3 58 22,2	23 56 56,5	+ 4 1 25,7	+ 1,4
☿ - - -	18	3 58 53,4	23 57 26,2	+ 4 1 27,2	+ 1,5
♃ - - -	19	3 59 24,6	23 57 56,1	+ 4 1 28,5	+ 1,3
♀ - - -	20	3 59 56,3	23 58 26,0	+ 4 1 30,3	+ 1,8
♄ - - -	21	4 0 27,9	23 58 56,0	+ 4 1 31,9	+ 1,6
♂ - - -	24	4 2 3,4	0 0 26,1	+ 4 1 37,3	+ 1,8
☿ - - -	25	4 2 33,6	0 0 56,0	+ 4 1 37,6	+ 0,3
♄ - - -	26	4 3 5,0	0 1 25,8	+ 4 1 39,2	+ 1,6
♀ - - -	27	4 3 36,1	0 1 55,4	+ 4 1 40,7	+ 1,5
♄ - - -	28	4 4 08,0	0 2 24,9	+ 4 1 43,1	+ 2,4
☉ - - -	29	4 4 40,2	0 2 54,2	+ 4 1 46,0	+ 2,9
☽ - - -	30	4 5 11,5	0 3 23,3	+ 4 1 48,2	+ 2,2
♂ - - -	31	4 5 41,9	0 3 52,2	+ 4 1 49,7	+ 1,5

68. Here it appears that the watch went conſiderably faſter the three firſt days than it did afterward; I therefore reject theſe three days, and take the difference between $4^{h}\ 1'\ 4'',6$, what the watch was too faſt on the fourth, and $4^{h}\ 1'\ 49'',7$, what it was too faſt on the 31ſt, and find it $45'',1$, which I divide by 27, the number of days elapſed, and the quotient, $1'',6704$, is the quantity which the watch gained on mean time in one day. It may be proper to repeat that the obſervations on the intermediate days are abſolutely neceſſary, though no uſe is made of them in deducing the rate of the watch's going; becauſe, without them, it would be impoſſible to tell whether the watch had altered its rate of going while under trial, or not; and, of courſe, whether it would be proper to make uſe of the whole time, or only a part of it; and what part.

69. But notwithſtanding the ſimplicity of the calculations, and the eaſe with which the obſervations are made, render this method of finding the rate of a watch vaſtly convenient in fixed obſervatories, it is not ſo well adapted to the ſkill and opportunities of ſeafaring men, in general, as ſome others are; for it requires not only a con-

ſiderable degree of knowledge in practical aſtronomy, but ſome time alſo, to get a tranſit inſtrument into the plane of the meridian. And if the inſtrument be not pretty exactly in the meridian, the obſerver will not only get the abſolute quantity of time, which the watch is too faſt, or too ſlow, wrong; but will, if there be any conſiderable change in the ſun's declination, while the watch is under trial, determine the rate of its going erroneouſly alſo. On this account it will be better to find the rate of the watch, by obſerving the tranſits of a fixed ſtar; and the abſolute time by obſervations of the ſun's altitude, taken with an Hadley's quadrant, from an artificial horizon. For, when a fixed ſtar is uſed, it is not neceſſary that the inſtrument be even near the meridian; though it will be convenient to place it as near it as a well-defined mark can be found, to adjuſt it to: and, therefore, the inſtrument may be ſet up, and adjuſted ready for obſervations of this kind, in the ſpace of an hour. Moreover, by this method, the computations are ſtill more ſimple than they are when the ſun is made uſe of; for, having taken the times by the watch when any fixed ſtar tranſits the vertical circle which the inſtrument moves in, every day, or as often as an opportunity offered, and for ſuch a length of time as may be thought neceſſary; put theſe times one under another, againſt the days of the month they were obſerved on. Take the difference between the firſt and ſecond, between the ſecond and third, and ſo on; and take alſo, the difference between each of theſe differences and 3′ 56″,55:* and theſe laſt differences will be the gain or loſs of the watch on mean time, in 24 hours. And the watch gains, if the firſt mentioned differences are leſs than 3′ 56″,55; but it loſes if they are greater. If the obſervations have been made regularly every day, and the watch has conſtantly loſt, or conſtantly gained on mean time, add the ſeveral gains or loſſes into one ſum, and divide it by the number of days the watch has been under trial, and the quotient will be the real gain or loſs which it makes in one day.

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* The fixed ſtars having no apparent annual motion, return to the meridian exactly in the time that the earth makes a revolution on its axis; while the ſun, having been carried, during the earth's revolution on its axis, ſome diſtance eaſtward, by its apparent annual motion in the ecliptic, will not return to the meridian until the earth, beſide making a complete revolution on its axis, has followed it through an arc which is equal to its diurnal motion in the ecliptic. And as this arc, on a medium, is equal to 59′ 8″,3, according to the beſt obſervtions, the mean ſolar day will be longer than the ſiderial day by 3′ 56″,55, which is the time that the earth takes to revolve through an arc of 59′ 8″,3.

70. If the obſervations have been repeated every day, and, on comparing them, the watch be found to have gained ſome days, and loſt others; take the ſum of all the gains, and the ſum of all the loſſes, ſeparately, ſubtract the leſs ſum from the greater, and divide the remainder by the number of days which the watch was under trial, and the quotient will be the real gain or loſs of the watch in one day, according as the ſum of the gains, or loſſes, is greateſt.

71. If, during the trial, the obſervations be omitted on ſome days, ſo that two or more days intervene; 3′ 56″,55 muſt be multiplied by the number of days which elapſe between the obſervations, and the difference between the times of the ſtar's tranſit muſt be compared with the product: the difference between them will be the gain or loſs of the watch in the interval between the obſervations; and, if this be divided by the number of days which have intervened, the quotient will be the gain or loſs in one day: but it is the gain or loſs in the whole interval which muſt be

taken in finding the real gain or loſs of the watch, at the end of the trial. The following example will explain the whole proceſs fully.

72. Suppoſe the times by a watch when the ſtar Aldebaran paſſed a tranſit inſtrument placed nearly in the meridian of Madras, were as follow: it is required to find how much the watch gained or loſt on mean time?

1794.	Obſ. Times of the ✱'s Tranſ.	Difference.	Diff. bet. m. Sol. & ſid. Day,	Watch gains, or loſes on mean T.	Remarks
	H. M. S.	M. S.	M. S.	S.	
♀ Jan. 3	9 22 17,42				
♄ - 4	9 18 20,73	3 56,69	3 56,55	− 0,14	
☉ - 5	9 14 24,36	3 56,37	3 56,55	+ 0,18	
☽ - 6	9 10 28,05	3 56,31	3 56,55	+ 0,24	
♂ - 7	9 6 31,48	3 56,57	3 56,55	− 0,02	
☿ - 8	9 2 33,87	3 57,61	3 56,55	− 1,06	
♃ - 9	8 58 36,53	3 57,34	3 56,55	− 0,79	
♄ - 11	8 50 45,07	7 51,46	7 53,10	+ 1,64	In 2 days
☉ - 12	8 46 49,46	3 55,61	3 56,55	+ 0,94	
☿ - 15	8 35 0,17	11 49,29	11 49,65	+ 0,36	In 3 days
♃ - 16	8 31 4,62	3 55,55	3 56,55	+ 1,00	
♀ - 17	8 27 8,21	3 56,41	3 56,55	+ 0,14	

73. Here it may be obſerved that the ſum of all the watch's gainings is 4″,50, and the ſum of all its loſings is 2″,01: the difference between them is 2″,49; which being divided by 14, the number of days the watch was under trial, will give 0″,178 for the daily gain of the watch.

74. The rate which a watch goes at is obtained this way with much leſs trouble than by any other; but the abſolute time is not given by it; nor, of courſe, how much the watch is too faſt, or too ſlow, for mean time at the meridian it is tried under. This muſt be found by obſerving altitudes of the ſun, immediately before the ſhip ſails, from the horizon of the ſea; or double altitudes of the ſun, from an artificial horizon, if the former be not open toward the eaſt or weſt at the place of obſervation.

EXAMPLE.

Admit that on the 17th, the laſt day on which the ſtar was obſerved, the following obſervations were made to find how much the watch was too faſt or too ſlow for mean time; the height of the obſerver's eye above the ſea being 27 feet.

Times by the watch.	Alt. of the Sun's L. L.
19^h 7′ 53″	10° 9′ 0″
8 34	16 15
9 17	24 45
9 58	32 30
10 42	41 00
11 22	48 45
6)57 46	6)172 15
19 9 37,7	10 28 42
	+ 6 26
	10 35 9 True altitude.

Appa. Time at Madras 19^h 23′
Long. of Madras in T. 5 22

Appa. Time at Green. 13 46

Sun's ſemidiameter .... 16′ 18″
Sun's horizontal parallax 9

16 27
Dip of the hor. 4′ 57½″ } 10 0½
Refraction 5 3

Correct. of the ſun's alt. 6 26½

Sun's dec. the 17th at noon Green. 20° 38′ 22″ S.
Correction for 13^h 46′ ſubtract 7 4

Sun's corrected declination ..... 20 31 18 S.

90°
Ship's latitude 13 4′ 54″ N. ſecant 10.01142

Co-latitude 76 55 6
Sun's declin. 20 31 18 S. ſecant 10.02847

Meridional alt. 56 23 48 N.S. 83289 } 64918 log. 4.81237
Sun's true alt. 10 35 9 N.S. 18371

Time from noon ... 4^h 52′ 57″,6 log-riſing 4.85226
24

Apparent time 19 7 2,4
Equation of time add 10 54,9

Mean time 19 17 57,3
Time by the watch 19 9 37,7

Watch too ſlow for m. T. 8 19,6

More ſets of altitudes may be taken if there be opportunities for it; by which means the deviation of the watch from mean time will be obtained with greater certainty.

75. As ſome, however, may not wiſh to put themſelves to the expence of, and others not to be encumbered with an additional inſtrument; and more ſtill not to give themſelves the trouble of learning the uſe of it; I ſhall now ſhew how the rate of a watch may be found, with equal accuracy, by Hadley's ſextant and an artificial horizon.

TO FIND THE RATE WHICH A WATCH GOES AT BY EQUAL ALTITUDES OF THE SUN.

76. In the morning, when the ſun is, at leaſt, four points from the meridian; but the nearer to the eaſt the better, place your artificial horizon * in a convenient

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* There are different contrivances for this purpoſe; but an oblong trough, filled with quickſilver, and ſheltered from the wind, is the only one that can be depended on. I have tried them all; and find that the circular one, with a bubble in the center, though, to appearance, perfect when firſt made, ſoon grows uſeleſs; the glaſs which covers the fluid altering its figure, I ſuppoſe, from the preſſure of the fluid againſt it. Thoſe which are formed by floating pieces of glaſs on quickſilver, though filled with the utmoſt care, are equally unſafe: for the inſtant the glaſs comes near any ſide of the veſſel it floats in, it loſes it horizontality, and will not recover it: the quickſilver muſt therefore be taken out, and put in again: but the trouble attending this operation is the leaſt part of the evil, for when the ſun is either riſing or falling faſt, the obſerver will not readily diſcover whether any alteration of this kind has happened or not. The beſt ſhelter for the quickſilver is, undoubtedly,

ſituation: take a Hadley's ſextant, ſcrew the teleſcope into its place, and bring the dark glaſſes to intervene, on each ſide the horizon glaſs. Having found that ſituation in which you can ſee the image of the ſun, in the quickſilver, conveniently, bring the inſtrument to your eye, and find the ſame image in the teleſcope: then move the index of the ſextant until you bring the image, reflected from the index glaſs, into the teleſcope alſo; and having made it paſs over, and a little way beyond the image on the quickſilver, fix the index by the ſcrew-clamp very ſecurely. Place a perſon at the watch, and obſerve carefully when the two neareſt limbs of the two images come exactly into contact, by the increaſing altitude of the ſun; and, the inſtant this hap-

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a roof formed by two plates of glaſs; the two ſides of each being ground perfectly plane, and parallel to one another: but, to prevent any bad effects from their being otherwiſe, care muſt be taken to put the roof on the ſame way; that is, ſo that the ſame ſide may be toward the obſerver in the afternoon that was toward him in the morning. The late Mr. Reuben Burrow who, whatever faults he might have, was certainly a very ingenious man, has recommended a piece of muſquetto curtain, ſtretched in a frame, as a good ſhelter for the quickſilver. See Aſiatic Reſearches, Vol. I. I have tried this mode of ſheltering the quickſilver, and found it anſwer the purpoſe very well, when the wind was not very ſtrong, and the ſun was reaſonably bright; the ſun's limb, however, is not ſo diſtinct as it is when the quickſilver is ſheltered by a glaſs roof.

pens, bid your aſſiſtant *mark* the ſecond, and parts of a ſecond, ſhewn by the watch when it happens. Theſe being written down, and the proper hour and minute annexed to them, bid him attend again to the watch, while you look out for the contact of the other limbs of the two images, which, by this time, will be got one on to the other, and approaching to a co-incidence. They will afterward begin to ſeparate; and when their limbs are again exactly in contact, bid your aſſiſtant *mark* the ſecond, and parts of a ſecond when it happened: put them down, and annex the proper hour and minute. The ſextant muſt now be put carefully away, without alteration in any reſpect, in a place where it will not be liable to be diſturbed; and another ſextant, or as many of them as are at hand, may be taken one after another, the ſame obſervations made with them, and the ſextants put away with the ſame care till the afternoon.

77. Eſtimate as near as you can, the time from noon when the laſt obſervation was made, allowing for the equation of time; and a little before that time in the afternoon ſet out your horizon, take the ſextant which the laſt obſervation was

made with in the morning, direct the teleſcope to the ſun's image in the quickſilver, and if it be near the time of obſervation, the image from the index glaſs will be in the teleſcope alſo; and a little attention will ſhew you that the images approach each other. Watch carefully till their neareſt limbs come into contact, and the inſtant they do bid your aſſiſtant *mark* the ſecond, and parts of a ſecond ſhewn by the watch. In the ſame manner mark the ſecond and parts of a ſecond, when the images having paſſed over each other, their limbs are again in contact at their ſeparation; which, as well as the ſecond and parts, when the former contact happened, with their proper hours and minutes annexed muſt be written down, oppoſite the obſervations made with the ſame ſextant in the morning. And the firſt obſervation in the afternoon muſt always be written oppoſite the latter morning obſervation; and the latter evening obſervation oppoſite the firſt morning obſervation.

79. Repeat theſe obſervations with each of the ſextants which were uſed in the morning, ſetting the obſervations oppoſite the obſervations made with the ſame ſextant in the morning; the firſt in the after-

noon againſt the latter morning one as before; and you will have as many ſets of obſervations, two in each ſet, as you uſed ſextants.

80. When you fix the index to the arch by the clamp, before the morning obſervation, it will not be amiſs if you ſet the index very exactly, to ſome even diviſion by means of the tangent ſcrew; and note what diviſion it was ſet to againſt the obſervation made with that ſextant. When this precaution is taken, you may examine, before you begin to obſerve in the afternoon, whether the index has been altered by any accident or not, and if it has, it may be placed to the ſame diviſion again. But if it be found that any one of the ſextants has been altered, the obſervations made with that ſextant ſhould be uſed with caution; and rejected if they be found to differ from thoſe made with the others, notwithſtanding the index of ſuch ſextant may have been reſtored to the proper diviſion before the afternoon obſervation.

81. The moſt proper time for making theſe obſervations, is when the ſun is nearly due eaſt and weſt. When, therefore, ſeveral obſervations are to be taken, it will be prudent to begin before the ſun comes

to the eaſt point of the horizon, in the morning, when it can be done; but not before ſix o'clock, nor before the ſun is 8 or 10 degrees high: indeed, too implicit a confidence muſt not be placed in obſervations made at theſe altitudes, if there be any material difference between the heights of the thermometer at the times of the morning and evening obſervations.

82. In order to deduce the time of noon from the obſervations, and by that means determine how much the watch is too faſt or too ſlow for mean time, add 24 hours to the time of the laſt obſervation in the afternoon, and take the time of the firſt obſervation in the morning from it, the remainder will be the interval between the obſervations. Take the half of this interval, and add it to the time of the morning obſervation, and it will give the time of apparent noon nearly. Take the ſun's longitude for noon at the place of obſervation, from page II. of the Nautical Almanac; with which, the latitude of the place, and the half-interval between the obſervations, take the equation to equal altitudes from the tables at the end of this work; and add it to, or ſubtract it from the time of noon, nearly, as the ſigns annexed

to the ſun's longitude direct, and it will give the time of apparent noon by the watch, according to this pair of obſervations. Repeat the operation with each pair of obſervations which may have been made, and you will have as many times of apparent noon by the watch as there are pairs of obſervations, which ought all to agree exactly; but as that can ſeldom be expected, and as there will generally be ſome ſmall differences between them, the mean of them all muſt be taken for the time of apparent noon by the watch.

EXAMPLE.

Admit that on the 25th of Auguſt, 1793, the following obſervations of equal altitudes were made at Quebec.

Thermometer.	Morning.			Afternoon.			Dou. Alt.		Thermometer.	
	H.	M.	S.	H.	M.	S.	°	′		
56°	19	26	53, 9	4	35	43, 3	45	00	67°	U. L.
	19	30	2, 3	4	32	35, 7				L. L.
58	20	4	25, 6	3	58	14, 6	57	30	68	U. L.
	20	7	36, 0	3	55	5, 0				L. L.

Upp. Limbs			Low. Limbs			Upp. Limbs			Low. Limbs			
H.	M.	S.	H.	M.	S.	H.	M.	S.	H.	M.	S.	
28	35	43,3	28	32	35,7	27	58	14,6	27	55	5,0	Aftern. obſer.
19	26	53,9	19	30	2,3	20	4	25,6	20	7	36,0	Morn. obſer.
9	8	49,4	9	2	33,4	7	53	49,0	7	47	29,0	Interval.
4	34	24,7	4	31	16,7	3	56	54,5	3	53	44,5	Half interval.
0	1	18,6	0	1	19,0	0	1	20,1	0	1	20,5	Noon nearly.
	+	18,3		+	18,2		+	17,1		+	17,0	Equa. Ta. I.
	−	1,1		−	1,2		−	1,5		−	1,5	Equa. Ta. II.
0	1	35,8	0	1	36,0	0	1	35,7	0	1	36,0	True time of noon by the watch.
											35,7	
											36,0	
											35,8	
										4)	143,5	

Time of noon by the watch	0h 1′ 35″,9
Mean time of appa. noon (Naut. Alm. p. II.)	0 1 35,3
Watch too faſt for mean time	00,6

And in this manner it may be found how much the watch is too faſt or too ſlow for mean time, every day at noon when equal altitudes of the ſun can be obtained; and, from thence, whether the watch gains or loſes, and how much, as in Art. 68.

PROBLEM VI.

83. To find the longitude at ſea by a Time-keeper.

RULE.

Obſerve the altitude of the ſun's limb, either in the morning or evening, when it is, at leaſt, three points of the compaſs from the meridian, and note the time when it was obſerved by the Time-keeper.

Multiply the daily rate of the watch by the number of days, which have elapſed ſince that on which the laſt obſervation was made for finding it, and add the product to the time ſhewn by the watch when the ſun's altitude was obſerved, if the watch be loſing, but ſubtract it from that time if the watch be gaining. To the ſum, or remainder, add what the watch was too ſlow, or ſubtract from it what the watch was too faſt for mean time at the place where its rate was found, on the day when the laſt obſervation was made for finding it, and the reſult will be the mean time at that place when the ſun's altitude was obſerved. To this time add the longitude of the place in time where the rate of the watch was found, if it be weſt; or ſubtract the longitude in time from it, if it be eaſt, and the ſum or remainder will be the mean time at Greenwich.

To this time find the ſun's declination by Problem III. and correct the obſerved altitude of the ſun's limb for the dip of the horizon, refraction, parallax, and ſemidiameter; with which, the latitude of the ſhip, and the ſun's declination, find the mean time at the ſhip, by Problem IV.

Take the difference between the mean time at the ſhip, and the mean time at Greenwich, and it will be the longitude of the ſhip in time; eaſt, if the time at the ſhip be greater than the time at Greenwich, but weſt if it be leſs.

EXAMPLE I.

After having found the rate of a watch to be gaining 1″,67, as in Art. 68, and that it was too faſt for mean time at Barbadoes, on the 31ſt of December, 1793, by 4^{h} 1′ 49″,7; let us ſuppoſe that on the 4th of February, 1794, in the afternoon, latitude 44° 26′ N. the following obſervations were taken: what was the longitude of the ſhip; the height of the obſerver's eye above the ſurface of the ſea being 21 feet?

Time by the Watch	Alt. of the ⊙'s L. L.		H. M. S.
		T.-keeper too faſt Dec. 31, 1793,	4 1 49,7
		Gain to Feb. 4, 1794 = $1'', 67 \times 35^{d}$.	+ 58,5
		Time-keeper too faſt Feb. 4,	4 2 48,2
$5^{h}\ 2'\ 51''$	$9^{\circ}\ 17'\ 15''$		
3 44	9 8 45	Sun's ſemi-diameter	$16'\ 16''$
4 40	8 59 30	Sun's horizontal parallax	9
5 49	8 50 00		
			16 25
4) 17 4	36 15 30	Dip of the horizon $4'\ 22''$	10 10
		Refraction 5 48	
5 4 16	9 3 52		
4 2 48	+ 6 15	Correction of the ſun's altitude	6 15
1 1 28	9 10 7	True altitude.	
3 58 45		Longitude of Barbadoes, W.	
5 0 13		Mean time at Greenwich.	

Sun's declination for noon at Greenwich	$16^{\circ}\ 3'\ 24''$ S.
Correction for time at Greenwich	— 3 31
Sun's correct declination	15 59 53 S.

	$90^{\circ}\ 00'$			
Ship's latitude	44 26	N. ſecant		10. 14626
Co-latitude	45 34			
Sun's declin.	16 00	S. ſecant		10.01715
Merid. altit.	29 34	N. S. 49344	33413 Log.	4. 52393
Sun's obſ. alt.	9 10	N. S. 15931		
Appa. time at the ſhip	$3^{h}\ 56'\ 29''$		Log-riſing	4. 68734
Equation of time, add	14 26			
Mean time at the ſhip	4 10 55			
Mean time at Green.	5 0 13			
Longitude in time	0 49 18 = 12° 19½ W.			

EXAMPLE II.

March 29th, 1794, latitude 55° 9′½ N. the following obſervations were made to determine the longitude by the ſame watch.

Time by the Watch	Alt. of the ☉'s L. L.		H. M. S.
		T.-keeper too faſt Dec. 31, 1793,	4 1 49,7
		Gain to Mar. 29, 1794 = 1″,67 × 88½ᵈ.	+ 2 27,8
18ʰ 8′ 30″	11° 27′ 15″	Time-keeper too faſt Mar. 29,	4 4 17,5
9 28	34 45		
10 26	42 00	Sun's ſemi-diameter	16′ 3″
11 27	49 30	Sun's parallax in altitude	9
12 32	58 00		
			16 12
5)52 23	5)211 30	Dip of the horizon 4′ 22″	− 8 53
18 10 28,6	11 42 18	Refraction 4 31	
4 4 17,5	+ 7 19	Correction of the ſun's altitude	7 19
14 6 11	11 49 37	True altitude.	
3 58 45	....	Longitude of Barbadoes, W.	
18 4 56	....	Mean time at Greenwich.	

Sun's declination for noon at Greenwich 3° 58′ 00″ N.
Correction for time at Greenwich ..... − 5 49

Sun's correct declination .... 3 52 11 N.

90° 00′
Ship's latitude 55 9½ N. ſecant 10.24313

Co-latitude 34 50½
Sun's declin. 3 52⅙ N. ſecant 10.00099

Merid. altit. 38 42⅔ Nat. S. 62539 } 42043 Log. 4.62369
Sun's obſ. alt. 11 49⅝ Nat. S. 20496 }

4ʰ 59′ 9″ Log-riſing 4.86781
24

Appa. time at the ſhip 19 0 51
Equation of time + 4 32

Mean time at the ſhip 19 5 23
Mean time at Green. 18 4 56

Longitude in time 1 0 27 = 15° 6′¾ Eaſt.

THE EXPLANATION AND USE OF THE *TABLES OF EQUATIONS* TO EQUAL ALTITUDES.

IN the Nautical Almanac for 1773, the Commiſſioners of the Board of Longitude, were pleaſed to publiſh a ſet of "Tables of Equations to Equal Altitudes," which I had computed, principally for amuſement, during the many dreary hours I paſſed on the coaſt of Hudſon's Bay in 1768, and 1769. That Almanac has long been out of print, and of courſe the tables are not to be procured; which has induced many gentlemen who are employed in, or amuſe themſelves with practical aſtronomy, to wiſh I would reprint them. In computing the tables which were publiſhed in the Nautical Almanac I made uſe of interpolations; and, before I reprinted them, I was deſirous of knowing how far theſe interpolations might be depended on: I therefore employed ſuch of the Boys who are under my care at Chriſt's

Hoſpital, as I found capable, in recomputing them, during their leiſure hours; and the tables which I now offer to the public, have been entirely recomputed with the utmoſt rigour: Every computation was made by two Boys, ſeparately, and at diſtant times; and the whole has been compared, and reviſed where any difference appeared, by myſelf. I have alſo, now, given the equations in ſeconds and decimal parts; which renders them more convenient than they were before; and, in ſome degree, more accurate.

In calculating theſe Tables I adhered to the formula which I made uſe of before; namely, the change in the ſun's delination, (during half the interval between the obſervations) multiplied by the co-ſecant of the meaſure of that half-interval, multiplied again by the tangent of the latitude of the place of obſervation, ± the ſaid change in the ſun's declination, multiplied by the tangent of the ſun's declination, and multiplied again by the co-tangent of the meaſure of the half-interval *. The

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* It is thus inveſtigated. Let PZC, Fig. 6, repreſent the meridian of the place, P the elevated pole; Z the zenith, ACF the almicanther the ſun is on at the time of obſervation, B the ſun's place at the morning obſervation. F its place when the obſervation was made in the afternoon, and ACD

numbers in Table I. are formed by multiplying the change in the ſun's declination

the parallel of declination which the ſun was on at the middle of the interval between the obſervations, and which cuts the almicanther in A and H. Deſcribe the hour circles P A, P B, P H, P F; and biſect the angle B P F, which is the meaſure of the interval between the obſervations, with the hour-circle P K G, and it is manifeſt that the angle B P G is the meaſure of half the interval between the obſervations; which being added to the time ſhewn by the clock or watch when the morning obſervation was made, will give the time when the ſun was on the hour-circle P K G; but the ſun was on the meridian P Z C at the inſtant of apparent noon; conſequently, the meaſure of the angle Z P G is the equation, which muſt be applied to the middle time between the two obſervations, to give the time of apparent noon by the clock or watch. It is moreover manifeſt from the figure itſelf that when the ſun is in the aſcending ſigns; that is, while it is approaching the elevated pole, the time of apparent noon precedes the middle time between the obſervations; and, conſequently, the equation muſt be ſubtracted from the middle time to give the time of apparent noon: and when the ſun is receding from the elevated pole, the equation muſt be added to the middle time to give the time of apparent noon.

As the variation of the ſun's declination in the firſt half-interval is never ſenſibly different from its variation in the latter, the angle A P B will, evidently, be equal to the angle H P F; and, conſequently, each of them is equal to Z P G, the equation ſought: make P K=P Z, and deſcribe the great circles K A and K B: then, in the ſpherical triangle B K P, the two ſides B K, K P, may be conſidered as being conſtant, while the ſide P B, which is the complement of the ſun's declination varies; and it is evident, that while P B varies the quantity B I the angle Z P B is altered by the quantity B P A, which has been ſhewn to be equal to the equation ſought. Now, by Art. 256, of Simpſon's Fluxions, or Theorem 23 of Cotes *de Eſtimatione Errorum in mixtâ Matheſi*, the <B P A : B I (the change in

during half the interval between the obſervations by the co-ſecant of the meaſure of that half-interval, and turning the products into time, at the rate of 15 degrees to an hour; the tangent of the latitude, which is found in the firſt part of the formula, being left out of the calculation to render the table general for all latitudes: conſequently, the numbers taken out of this table muſt be multiplied by the tangent of the geographical latitude; and, if that latitude be ſouth, it will change the ſign of the equation, becauſe the table is adapted to northern latitudes.

The ſecond part, which conſiſts of the continual products formed by multiplying the change in the ſun's declination during

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the ſun's declination) 1 : cotan. $<B$: ſin. BP. Conſequently, $<BPA = \frac{BI \times \text{cotan.} <B}{\text{ſin. } BP}$. But it is ſhewn by the writers on ſpherical trigonometry, that, putting 1 for the radius, the cotan. of $<B = \frac{\text{ſin. } PB \times \text{cot. } PK}{\text{ſin. } <P} \pm \frac{\text{coſ. } PB \times \text{coſ. } <P}{\text{ſin. } <P}$. Therefore the $<BPA = \frac{BI \times \text{ſin. } PB \times \text{cot. } PK}{\text{ſin. } PB \times \text{ſin. } <P} \pm \frac{BI \times \text{coſ. } PB \times \text{coſ. } <P}{\text{ſin. } PB \times \text{ſin. } <P}$. Or, dividing by ſin. PB, and putting the coſecant of $<P$ for $\frac{1}{\text{ſin. } <P}$, in the firſt term, and cotang. for $\frac{\text{coſine}}{\text{ſine}}$, in the ſecond term, we obtain $<BPA = BI \times \text{co-ſec. } <P \times \text{cot. } PK \pm BI \times \text{cot. } PB \times \text{cot. } <P$: in which, BI is conſidered as affirmative when PB, the ſun's diſtance from the elevated pole, is increaſing; and negative when it is decreaſing.

half the interval between the obſervations, by the co-tangent of the meaſure of that half-interval, and by the tangent of the ſun's declination, is common to all latitudes; and theſe products, turned into time, are contained in Table II.

Theſe tables may be made to depend either on the ſun's longitude or its declination; but as the ſun's declination is liable to ſome objections, and no advantage can be obtained by uſing it, I have made them depend on the ſun's longitude, as uſual.

The method of taking numbers out of the tables will be beſt explained by an example:

Let the ſun's longitude be $2^s\ 13^\circ\ 43'$.
The half-interval $5^h\ 17'\ 16'' = 5^h\ 17',3$.
And the latitude of the place $51^\circ\ 31'$ N.

Firſt in Table I. if the ſun's longitude be ſuppoſed $2^s\ 10^\circ$, the equation for the half-interval $5^h\ 10'$ will be $7'',44$; and for the half-interval $5^h\ 20'$ it will be $7'',62$; the difference is $0'',18$. Now $10'$ is to $7',3$ as $0'',18$ is to $0'',13$; which being added to $7'',44$, the former of them, becauſe the equation increaſes, gives $7'',57$ for the equation when the ſun's longitude is $2^s\ 10^\circ$.

If the ſun's longitude be taken $2^s\ 15^\circ$, the equation will be $5'',65$, ſuppoſing the half-interval 5^{h} 10′, and 5″,78, ſuppoſing it 5^{h} 20′: the difference is 0″,13. And 10 is to 7′,3 as 0″,13 is to 0″,09; which being added to the former, gives 5″,74 for the equation when the ſun's longitude is 2^{s} 15°. The difference between this and 7″,57, the equation when the ſun's longitude was ſuppoſed 2^{s} 10°, is 1″,83. And 300′, (5°) is to 223′, (3° 43′) as 1″,83 is to 1″,36: which being ſubtracted from 7″,57, becauſe the equation decreaſes this way, leaves 6″,21 for that part of the equation which is contained in Table I. But this number muſt be multiplied by the tangent of the latitude (51° 31′ N.). I, therefore, find its logarithm, in Table XVIII. of the Requiſite Tables, which is 0.79309, and add to it 0.09965, the tangent of 51° 31′, in Table XIX. which makes 0.89274, the logarithm of 7″,81 in Table XVIII, the firſt part of the equation; which muſt be ſubtracted from the middle time becauſe the ſign in the table is —. If the latitude had been ſouth, it would have changed the ſign to +.

In Table II. ſuppoſing the ſun's longitude to be 2^{s} 10° the equation is 0″,65 when the half-interval is 5^{h} 10′, and 0″,53 when it is 5^{h} 20′; the difference is 0″,12.

And 10′ is to 7′,3 as 0″,12 is to 0″,09; which being ſubtracted from 0″,65, becauſe the equation decreaſes, leaves 0″,56 for the equation when the ſun's longitude is 2^s 10°. Again, the ſun's longitude being taken 2^s 15°, the equation will be 0″,51, when the half-interval is 5^h 10′, and 0″,42 when it is 5^h 20′; the difference between them is 0″,09. And 10′ is to 7′,3 as 0″,09 is to 0″,07; which being ſubtracted from 0″,51, leaves 0″,44 for the equation when the ſun's longitude is 2^s 15°. The difference between 0″,44 and 0″,56 (the equation when the ſun's longitude is 2^s 10°) is 0″,12. And 300′, (5°) is to 223′, (3° 43′) as 0″,12 is to 0″,09; which being taken from 0″,56, becauſe the equation is decreaſing this way alſo, leaves 0″,47 for the proper equation from Table II. which is additive to the middle time, becauſe the ſign in the table is +. And the difference between this and 7″,81, the equation from Table I. (becauſe they have contrary ſigns), namely, 7″,34 is the equation ſought: ſubtractive, becauſe the greater part is ſo.

Another example will make every thing relative to theſe tables perfectly plain to the meaneſt capacity.

On the 7th of October 1793, the following times, when the ſun had equal altitudes were obſerved at the Cape of Good Hope, latitude 33° 56′ S. longitude 18° 23′ eaſt.

Thermome.	Lower Wire.	Middle Wire.	Upper Wire.		
57°	21′ 38″,8	21h 22′ 32″,6	23′ 26″,0	⊙'s U. L.	Morn.
	25 31 ,2	21 26 24 ,4	27 17 ,8	⊙'s L. L.	
62°	33 11 ,2	2 32 17 ,6	31 24 ,4	⊙'s L. L.	Aftern.
	37 3 ,2	2 36 9 ,8	35 16 ,6	⊙'s U. L.	

Sun's Upper Limb.			Sun's Lower Limb.			
H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	H. M. S.	
2 37 3,2	2 36 9,8	2 35 16,6	2 33 11,2	2 32 17,6	2 31 24,4	T. of aft obs.
24	24	24	24	24	24	Add.
26 37 3,2	26 36 9,8	26 35 16,6	26 33 11,2	26 32 17,6	26 31 24,4	Af.obs.+24h
21 21 38,8	21 22 32,6	21 23 26,0	21 25 31,2	21 26 24,4	21 27 17,8	T.of mor.obs.
5 15 24,4	5 13 37,2	5 11 50,6	5 7 40,0	5 5 53,2	5 4 6,6	Interval.
2 37 42,2	2 36 48,6	2 35 55,3	2 33 50,0	2 32 56,6	2 32 3,3	Half-interv,
23 59 21,0	23 59 21,2	23 59 21,3	23 59 21,2	23 59 21,0	23 59 21,1	T. n. nearly.
,2						
,3	Sun's long. for noon at Greenwich, October 7th					6^s 14° 39′,0
,2	18° 23′ E. longitude under 2′ 28″ (hourly motion ⊙) gives ...					— 3,0
,0						
,1	Sun's longitude for noon at the Cape					6 14 36,0
6),8						
23 59 21,13	The mean : and 2h 34′ 52″,$\frac{2}{3}$ is the mean half-interval.					

Firſt ; in Table I. with ⊙'s long. 6^s 10° and half-interval 2h 30′ the equa. is + 15″,92

⊙'s long. 6 10 and half-interval 2h 40′ the equa. is + 16 ,08

The difference is 0 ,16

Now 10′ is to $4'\frac{7}{8}$, as 0″,16 is to 0″,08; which being added to 15″,92, becauſe the equation increaſes with the interval, gives +16″,00 for the equation when the ſun's longitude is 6^s 10°. Again,

⊙'s long. 6^s 15° half-int. 2^h 30′ the equa. will be +15″,71
⊙'s long. 6^s 15° half-int. 2^h 40′ the equation is +15 ,87

The difference is 0 ,16

And 10′ is to $4'\frac{7}{8}$, as 0″,16 is to 0″,08; which being added to 15″,71, gives +15″,79 for the equation when the ſun's longitude is 6^s 15°. The difference between this and 16″,00, the equation when the ſun's longitude was 6^s 10°, is 0″,21. Then 300′, (5°) is to 276′, (4° 36′) as 0″,21 is to 0″,19; which being ſubtracted from 16,″00, becauſe the equation decreaſes this way, gives +15″,81 for the equation from Table I. But this number muſt be multiplied by the tangent of the latitude (33° 56′ S.) I therefore find its logarithm, which is 1.19893, and add 9.82790 (the tangent of the latitude) to it; and the ſum (1.02683) will be the logarithm of 10″,64, the firſt part of the equation; which is ſubtractive, becauſe the latitude being ſouth changes the ſign from + to —.

In Table II. ſuppoſing the ſun's longitude to be $6^{s}\ 10^{\circ}$ and the half-interval $2^{h}\ 30'$; the equation will be $-0'',87$; and, if the longitude remain the ſame, and the half-interval be taken $2^{h}\ 40'$, it will be $-0'',85$. The difference is $0'',02$; and $10'$ is to $4'\frac{7}{8}$ is $0'',02$ is to $0'',01$; which being ſubtracted from $-0'',87$, becauſe this part of the equation decreaſes as the half-interval increaſes, gives $-0'',86$ for the equation, when the ſun's longitude is $6^{s}\ 10^{\circ}$. If the ſun's longitude be ſuppoſed $6^{s}\ 15^{\circ}$, the equation will be $-1'',29$, when the half-interval is $2^{h}\ 30'$, and $-1'',26$ when it is $2^{h}\ 40'$. The difference between them is $0'',03$; and $10'$ is to $4\frac{7}{8}$ is $0'',03$ is to $0'',01$; which being ſubtracted from $-1'',29$, gives $-1'',28$ for the equation when the ſun's longitude is $6^{s}\ 15^{\circ}$. The difference between this and $-0'',86$ (the equation when the ſun's longitude is $6^{s}\ 10^{\circ}$) is $0'',42$: and $300'$, (5°) is to $276'$, ($4^{\circ}\ 36'$) as $0'',42$ is to $0'',39$; which being added to $-0'',86$, becauſe the equation increaſes this way, gives $-1,''25$ for the ſecond part of the equation. And the two parts being added together, becauſe they are both $-$, gives $-11'',89$ for the whole equation. This being ſubtracted from 23^h 59′ 21″,13, the time of noon nearly, gives 23^h 59′ 9″,24 for the true time of apparent noon by the watch.

The equation of time for noon at Green. is	–	12′ 19″,3
And 24^h : 1^h 14′(lon. in time) : : 16″,7 (d. diff.) :	–	0 ,8
Equation of time for noon at the Cape ...	–	12 18 ,5
Which being ſubtracted from		24^h
Leaves the mean time of apparent noon	=	23 47 41 ,5
Time of noon by the watch		23 59 9 ,2
Watch too faſt for mean time		11 27 ,7

REMARK.

When the clock's rate of going differs very conſiderably from mean ſolar time, and great accuracy is required, the half-interval muſt be corrected according to the following proportion, *viz.* As the time ſhewn by the clock in 24 hours is to 24 hours, ſo is the half-interval by the clock to the half-interval in mean ſolar time. And, when the equation is found, it muſt be reduced into time of the clock's rate of going, by ſaying, as 24 hours is to the time ſhewn by the clock in 24 hours, ſo is the equation found by the preceding directions to the equation required in this caſe. But unleſs very great accuracy be inſiſted on, and the clock's rate of going differ more thon 4 or 5 minutes a-day from mean ſolar time, this correction can never be neceſſary.

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Fig. 3

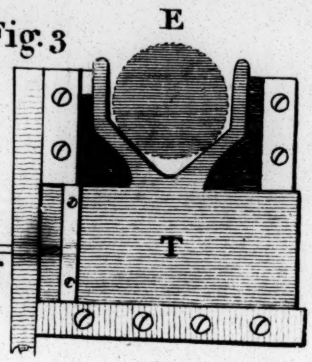


Fig. 4

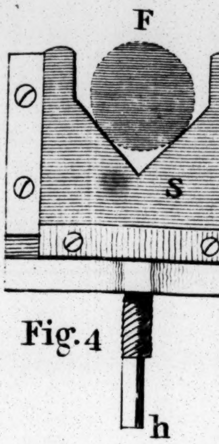
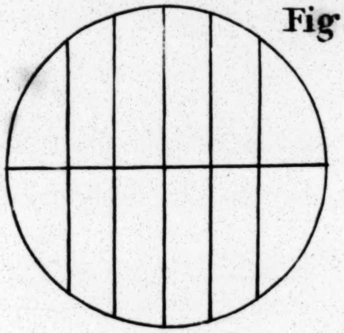


Fig. 5



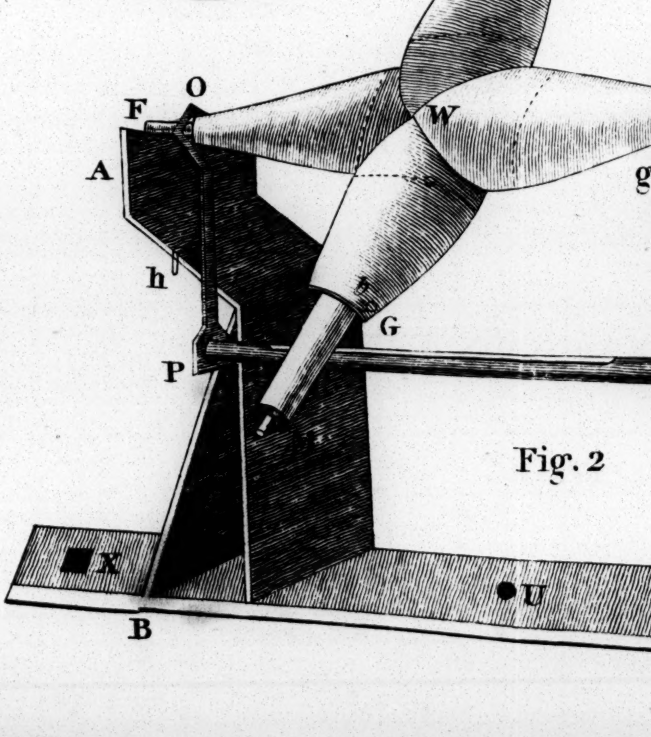


Fig. 2

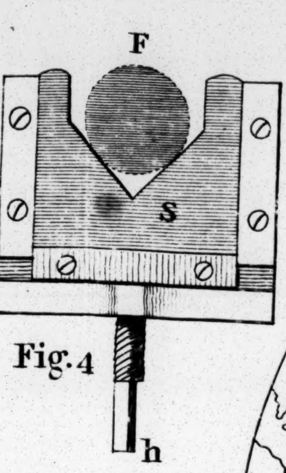


Fig. 4

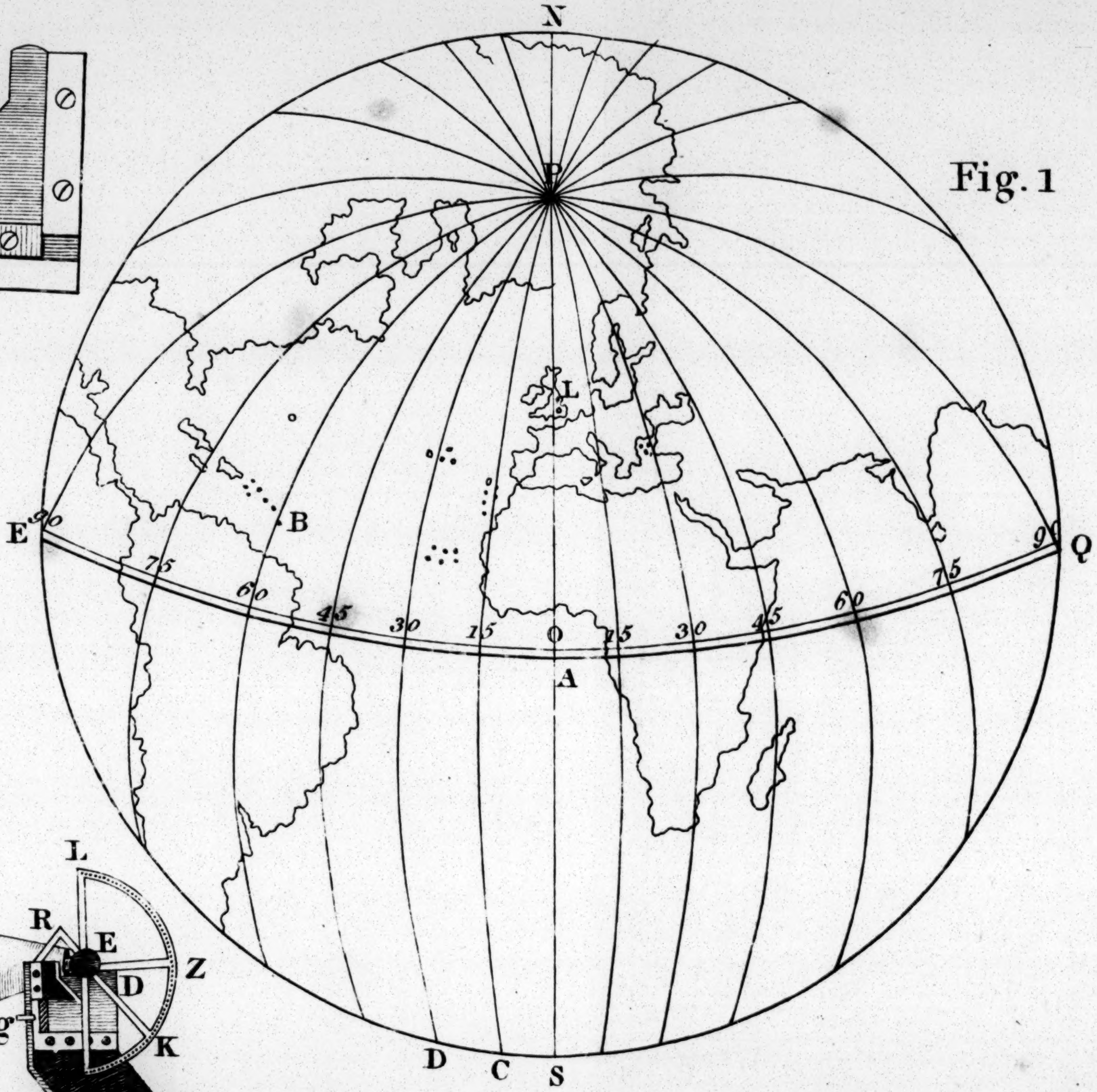


Fig. 1

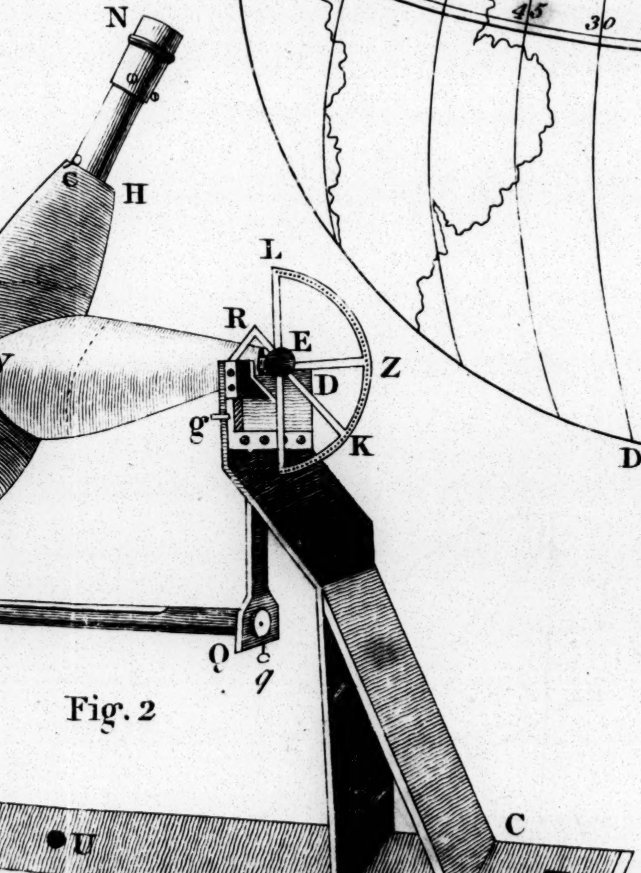


Fig. 2

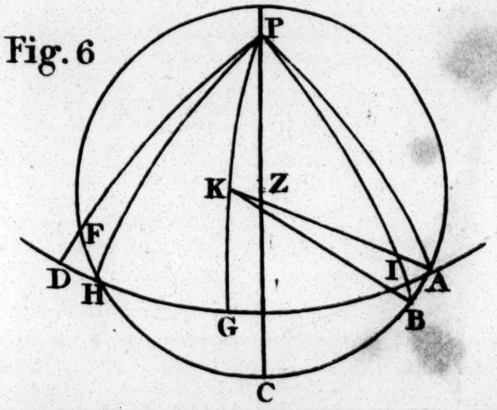


Fig. 6

Neele sculp! 352 Strand.

TABLES

OF

EQUATIONS

TO

EQUAL ALTITUDES.

C

S
C

I

II

II

IV

V

VI

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		I . 30	I. 40	I. 50	II. 0	II. 10	II. 20	II. 30
S.	D.	S.	S.	S.	S.	S.	S.	S.
O —	0	15,47	15,57	15,68	15,79	15,92	16,06	16,21
	5	15,38	15,48	15,58	15,70	15,83	15,97	16,12
	10	15,19	15,28	15,38	15,50	15,62	15,76	15,91
	15	14,90	14,99	15,09	15,20	15,32	15,46	15,61
	20	14,51	14,60	14,69	14,80	14,92	15,05	15,20
	25	14,02	14,10	14,20	14,31	14,42	14,55	14,69
I —	0	13,44	13,53	13,62	13,72	13,83	13,95	14,08
	5	12,76	12,84	12,93	13,03	13,14	13,25	13,37
	10	11,99	12,06	12,14	12,23	12,33	12,44	12,56
	15	11,12	11,19	11,27	11,35	11,44	11,54	11,65
	20	10,16	10,22	10,29	10,37	10,46	10,55	10,65
	25	9,12	9,17	9,23	9,30	9,38	9,46	9,55
II —	0	7,99	8,04	8,09	8,15	8,22	8,29	8,37
	5	6,78	6,82	6,87	6,92	6,98	7,04	7,11
	10	5,51	5,55	5,59	5,63	5,67	5,72	5,78
	15	4,18	4,21	4,24	4,27	4,30	4,34	4,38
	20	2,81	2,83	2,85	2,87	2,90	2,92	2,95
	25	1,41	1,42	1,43	1,44	1,46	1,47	1,48
III +	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,41	1,42	1,43	1,44	1,45	1,47	1,48
	10	2,81	2,83	2,85	2,87	2,89	2,92	2,95
	15	4,17	4,20	4,23	4,26	4,29	4,33	4,37
	20	5,49	5,52	5,56	5,60	5,65	5,70	5,75
	25	6,75	6,79	6,84	6,89	6,95	7,01	7,07
IV +	0	7,94	7,99	8,05	8,11	8,17	8,24	8,32
	5	9,06	9,11	9,17	9,24	9,32	9,40	9,49
	10	10,09	10,15	10,22	10,30	10,38	10,47	10,57
	15	11,03	11,10	11,18	11,26	11,35	11,45	11,56
	20	11,89	11,96	12,04	12,13	12,23	12,33	12,45
	25	12,65	12,72	12,81	12,91	13,01	13,12	13,25
V +	0	13,31	13,40	13,49	13,59	13,70	13,82	13,95
	5	13,88	13,97	14,07	14,17	14,28	14,41	14,54
	10	14,35	14,44	14,54	14,65	14,77	14,90	15,04
	15	14,74	14,83	14,93	15,04	15,16	15,30	15,44
	20	15,03	15,12	15,22	15,33	15,46	15,59	15,74
	25	15,22	15,31	15,41	15,53	15,65	15,79	15,94
VI +	0	15,31	15,40	15,51	15,62	15,75	15,89	16,04

☉'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		II. 40	II. 50	III. 0	III.10	III.20	III.30	III.40
S.	D.	S.	S.	S.	S.	S.	S.	S.
O	− 0	16,38	16,56	16,75	16,96	17,18	17,42	17,67
	5	16,28	16,46	16,65	16,86	17,08	17,32	17,57
	10	16,08	16,25	16,44	16,64	16,86	17,10	17,35
	15	15,77	15,94	16,12	16,32	16,54	16,77	17,01
	20	15,35	15,52	15,70	15,89	16,10	16,32	16,56
	25	14,84	15,00	15,17	15,36	15,56	15,78	16,01
I	− 0	14,22	14,37	14,54	14,72	14,92	15,13	15,35
	5	13,51	13,65	13,81	13,98	14,17	14,36	14,57
	10	12,69	12,83	12,98	13,14	13,31	13,49	13,69
	15	11,77	11,90	12,04	12,19	12,35	12,52	12,70
	20	10,75	10,87	11,00	11,14	11,28	11,44	11,61
	25	9,65	9,76	9,87	9,99	10,12	10,26	10,41
II	− 0	8,46	8,55	8,65	8,76	8,87	8,99	9,12
	5	7,18	7,26	7,35	7,44	7,54	7,64	7,75
	10	5,84	5,90	5,97	6,04	6,12	6,21	6,30
	15	4,43	4,48	4,53	4,59	4,65	4,71	4,78
	20	2,98	3,01	3,05	3,09	3,13	3,17	3,22
	25	1,50	1,51	1,53	1,55	1,57	1,59	1,62
III	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,49	1,51	1,53	1,55	1,57	1,59	1,61
	10	2,98	3,01	3,04	3,08	3,12	3,16	3,21
	15	4,42	4,47	4,52	4,57	4,63	4,70	4,77
	20	5,81	5,87	5,94	6,02	6,10	6,18	6,27
	25	7,14	7,22	7,31	7,40	7,50	7,60	7,71
IV	+ 0	8,41	8,50	8,60	8,71	8,82	8,94	9,07
	5	9,59	9,69	9,80	9,93	10,06	10,20	10,34
	10	10,68	10,80	10,93	11,06	11,20	11,36	11,53
	15	11,68	11,81	11,94	12,09	12,25	12,42	12,60
	20	12,58	12,72	12,86	13,02	13,19	13,38	13,57
	25	13,38	13,53	13,69	13,86	14,04	14,23	14,44
V	+ 0	14,09	14,24	14,41	14,59	14,78	14,98	15,20
	5	14,69	14,85	15,03	15,21	15,41	15,62	15,85
	10	15,20	15,36	15,54	15,73	15,94	16,16	16,39
	15	15,60	15,77	15,95	16,15	16,36	16,59	16,83
	20	15,90	16,07	16,26	16,46	16,68	16,91	17,16
	25	16,10	16,28	16,47	16,67	16,89	17,12	17,37
VI	+ 0	16,20	16,38	16,57	16,78	17,00	17,23	17,48

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		III.50	IV. 0	IV.10	IV.20	IV.30	IV.40	IV.50
S.	D.	S.	S.	S.	S.	S.	S.	S.
O	− 0	17,94	18,23	18,54	18,87	19,22	19,60	20,01
	5	17,84	18,13	18,44	18,77	19,12	19,49	19,89
	10	17,62	17,90	18,20	18,53	18,88	19,25	19,64
	15	17,27	17,55	17,85	18,17	18,51	18,87	19,26
	20	16,82	17,09	17,38	17,69	18,02	18,37	18,75
	25	16,26	16,52	16,80	17,10	17,42	17,76	18,12
I	− 0	15,59	15,84	16,11	16,40	16,70	17,03	17,38
	5	14,80	15,04	15,29	15,56	15,86	16,17	16,50
	10	13,90	14,13	14,37	14,63	14,90	15,19	15,50
	15	12,90	13,11	13,33	13,57	13,82	14,09	14,38
	20	11,79	11,98	12,18	12,40	12,63	12,88	13,14
	25	10,57	10,74	10,93	11,12	11,33	11,55	11,79
II	− 0	9,26	9,41	9,57	9,74	9,93	10,12	10,33
	5	7,87	8,00	8,14	8,28	8,43	8,60	8,77
	10	6,40	6,50	6,61	6,72	6,85	6,99	7,13
	15	4,85	4,93	5,01	5,10	5,20	5,30	5,41
	20	3,27	3,32	3,37	3,43	3,50	3,57	3,64
	25	1,64	1,67	1,70	1,73	1,76	1,79	1,83
III	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,64	1,66	1,69	1,72	1,76	1,79	1,83
	10	3,26	3,31	3,37	3,43	3,50	3,56	3,63
	15	4,84	4,92	5,00	5,09	5,19	5,29	5,40
	20	6,37	6,47	6,58	6,70	6,82	6,96	7,10
	25	7,83	7,96	8,10	8,24	8,39	8,56	8,73
IV	+ 0	9,21	9,36	9,52	9,69	9,87	10,06	10,27
	5	10,50	10,68	10,86	11,05	11,26	11,48	11,71
	10	11,70	11,89	12,10	12,31	12,54	12,79	13,05
	15	12,79	13,00	13,22	13,46	13,71	13,98	14,27
	20	13,78	14,01	14,25	14,50	14,77	15,06	15,37
	25	14,66	14,90	15,15	15,42	15,71	16,02	16,35
V	+ 0	15,44	15,69	15,96	16,24	16,54	16,86	17,21
	5	16,10	16,36	16,64	16,94	17,26	17,59	17,95
	10	16,64	16,91	17,20	17,51	17,84	18,19	18,56
	15	17,09	17,37	17,67	17,98	18,31	18,67	19,06
	20	17,42	17,70	18,00	18,32	18,67	19,04	19,43
	25	17,64	17,93	18,23	18,56	18,91	19,28	19,67
VI	+ 0	17,75	18,04	18,35	18,68	19,03	19,40	19,79

☉'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		V. 0	V. 10	V. 20	V. 30	V. 40	V. 50	VI. 0
S.	D.	S.	S.	S.	S.	S.	S.	S.
0	– 0	20,44	20,90	21,38	21,90	22,46	23,05	23,69
	5	20,32	20,77	21,25	21,77	22,32	22,91	23,55
	10	20,06	20,51	20,99	21,50	22,04	22,62	23,25
	15	19,67	20,11	20,58	21,08	21,62	22,19	22,80
	20	19,16	19,59	20,05	20,54	21,06	21,61	22,21
	25	18,51	18,93	19,37	19,84	20,34	20,88	21,46
I	– 0	17,75	18,15	18,57	19,02	19,50	20,02	20,57
	5	16,85	17,23	17,63	18,06	18,52	19,01	19,53
	10	15,83	16,19	16,57	16,97	17,40	17,86	18,35
	15	14,69	15,02	15,37	15,74	16,14	16,57	17,03
	20	13,42	13,72	14,04	14,38	14,75	15,14	15,56
	25	12,04	12,31	12,59	12,90	13,23	13,58	13,96
II	– 0	10,55	10,78	11,03	11,30	11,59	11,90	12,23
	5	8,96	9,16	9,37	9,60	9,85	10,11	10,39
	10	7,28	7,44	7,62	7,80	8,00	8,21	8,44
	15	5,53	5,65	5,78	5,92	6,07	6,23	6,41
	20	3,72	3,80	3,89	3,98	4,08	4,19	4,31
	25	1,87	1,91	1,95	2,00	2,05	2,10	2,16
III	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,87	1,91	1,95	2,00	2,05	2,10	2,16
	10	3,71	3,79	3,88	3,97	4,07	4,18	4,30
	15	5,51	5,63	5,77	5,91	6,06	6,22	6,39
	20	7,25	7,41	7,59	7,77	7,97	8,18	8,41
	25	8,92	9,12	9,33	9,56	9,80	10,06	10,34
IV	+ 0	10,49	10,73	10,98	11,25	11,54	11,84	12,16
	5	11,96	12,23	12,52	12,82	13,14	13,49	13,86
	10	13,33	13,63	13,94	14,28	14,65	15,04	15,45
	15	14,57	14,90	15,25	15,62	16,01	16,43	16,89
	20	15,70	16,05	16,42	16,82	17,25	17,71	18,19
	25	16,70	17,07	17,47	17,90	18,35	18,84	19,36
V	+ 0	17,58	17,98	18,40	18,85	19,32	19,83	20,38
	5	18,34	18,75	19,18	19,64	20,14	20,67	21,25
	10	18,96	19,39	19,84	20,32	20,84	21,39	21,97
	15	19,47	19,90	20,36	20,86	21,39	21,96	22,56
	20	19,84	20,28	20,76	21,26	21,80	22,38	23,00
	25	20,09	20,54	21,02	21,53	22,08	22,66	23,29
VI	+ 0	20,22	20,67	21,15	21,67	22,22	22,81	23,44

☉'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		I. 30	I. 40	I. 50	II. 0	II. 10	II. 20	II. 30
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI +	0	15, 31	15, 41	15, 51	15, 62	15, 75	15, 89	16, 04
	5	15, 30	15, 40	15, 50	15, 61	15, 74	15, 88	16, 03
	10	15, 20	15, 29	15, 39	15, 51	15, 63	15, 77	15, 92
	15	14, 99	15, 08	15, 19	15, 30	15, 42	15, 56	15, 71
	20	14, 69	14, 78	14, 88	14, 99	15, 11	15, 24	15, 39
	25	14, 28	14, 37	14, 46	14, 57	14, 69	14, 82	14, 96
VII +	0	13, 76	13, 85	13, 95	14, 05	14, 16	14, 29	14, 42
	5	13, 14	13, 22	13, 31	13, 41	13, 52	13, 64	13, 77
	10	12, 41	12, 49	12, 57	12, 66	12, 76	12, 87	13, 00
	15	11, 57	11, 64	11, 71	11, 80	11, 90	12, 01	12, 12
	20	10, 62	10, 68	10, 75	10, 83	10, 92	11, 02	11, 13
	25	9, 57	9, 63	9, 69	9, 76	9, 84	9, 93	10, 03
VIII +	0	8, 42	8, 47	8, 53	8, 59	8, 66	8, 74	8, 82
	5	7, 18	7, 22	7, 27	7, 32	7, 38	7, 45	7, 52
	10	5, 85	5, 88	5, 92	5, 97	6, 02	6, 07	6, 13
	15	4, 45	4, 48	4, 51	4, 54	4, 58	4, 62	4, 66
	20	3, 00	3, 02	3, 04	3, 06	3, 09	3, 11	3, 14
	25	1, 51	1, 52	1, 53	1, 54	1, 55	1, 56	1, 58
IX −	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
	5	1, 51	1, 52	1, 53	1, 54	1, 55	1, 57	1, 58
	10	3, 00	3, 02	3, 04	3, 07	3, 09	3, 12	3, 15
	15	4, 46	4, 49	4, 52	4, 55	4, 59	4, 63	4, 67
	20	5, 87	5, 90	5, 94	5, 99	6, 04	6, 09	6, 15
	25	7, 20	7, 24	7, 29	7, 35	7, 41	7, 48	7, 55
X −	0	8, 46	8, 51	8, 57	8, 63	8, 70	8, 78	8, 86
	5	9, 63	9, 69	9, 75	9, 82	9, 90	9, 99	10, 09
	10	10, 70	10, 76	10, 83	10, 91	11, 00	11, 10	11, 21
	15	11, 66	11, 73	11, 81	11, 90	12, 00	12, 10	12, 21
	20	12, 51	12, 59	12, 68	12, 77	12, 87	12, 99	13, 11
	25	13, 26	13, 34	13, 43	13, 53	13, 64	13, 76	13, 89
XI −	0	13, 89	13, 98	14, 08	14, 18	14, 29	14, 42	14, 55
	5	14, 42	14, 51	14, 61	14, 72	14, 84	14, 97	15, 11
	10	14, 84	14, 93	15, 03	15, 14	15, 27	15, 40	15, 55
	15	15, 15	15, 25	15, 35	15, 46	15, 59	15, 73	15, 88
	20	15, 36	15, 46	15, 57	15, 68	15, 80	15, 94	16, 10
	25	15, 47	15, 56	15, 67	15, 78	15, 91	16, 05	16, 21
XII −	0	15, 48	15, 57	15, 68	15, 79	15, 92	16, 06	16, 22

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		II. 40	II. 50	III. 0	III. 10	III. 20	III. 30	III. 40
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	16,21	16,38	16,57	16,78	17,00	17,23	17,48
	5	16,20	16,37	16,56	16,77	16,99	17,22	17,47
	10	16,08	16,26	16,45	16,65	16,87	17,10	17,35
	15	15,87	16,04	16,23	16,43	16,64	16,87	17,12
	20	15,55	15,72	15,90	16,09	16,30	16,53	16,77
	25	15,11	15,28	15,46	15,65	15,86	16,08	16,31
VII	+ 0	14,57	14,73	14,90	15,08	15,28	15,49	15,72
	5	13,91	14,06	14,22	14,40	14,59	14,79	15,01
	10	13,13	13,27	13,42	13,59	13,77	13,96	14,17
	15	12,24	12,37	12,51	12,67	12,84	13,02	13,21
	20	11,24	11,36	11,49	11,63	11,79	11,96	12,13
	25	10,13	10,24	10,36	10,48	10,62	10,77	10,93
VIII	+ 0	8,91	9,01	9,11	9,22	9,34	9,47	9,61
	5	7,59	7,67	7,76	7,86	7,96	8,07	8,19
	10	6,19	6,26	6,33	6,41	6,49	6,58	6,68
	15	4,71	4,76	4,82	4,88	4,94	5,01	5,08
	20	3,18	3,21	3,25	3,29	3,33	3,38	3,43
	25	1,60	1,62	1,64	1,66	1,68	1,70	1,73
IX	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,60	1,62	1,64	1,66	1,68	1,70	1,73
	10	3,18	3,21	3,25	3,28	3,33	3,38	3,43
	15	4,72	4,77	4,83	4,89	4,95	5,02	5,09
	20	6,21	6,28	6,35	6,43	6,51	6,60	6,70
	25	7,62	7,70	7,79	7,89	8,00	8,11	8,23
X	− 0	8,95	9,05	9,15	9,27	9,39	9,52	9,66
	5	10,19	10,30	10,42	10,55	10,69	10,83	10,99
	10	11,32	11,44	11,58	11,72	11,87	12,04	12,21
	15	12,34	12,48	12,62	12,77	12,94	13,12	13,31
	20	13,24	13,39	13,54	13,71	13,89	14,08	14,29
	25	14,03	14,18	14,35	14,53	14,72	14,92	15,14
XI	− 0	14,70	14,86	15,04	15,23	15,42	15,63	15,86
	5	15,26	15,43	15,61	15,80	16,01	16,23	16,47
	10	15,71	15,88	16,06	16,26	16,48	16,71	16,95
	15	16,04	16,21	16,40	16,60	16,82	17,06	17,31
	20	16,26	16,44	16,63	16,83	17,05	17,29	17,54
	25	16,37	16,55	16,74	16,95	17,17	17,41	17,66
XII	− 0	16,38	16,56	16,75	16,96	17,18	17,42	17,67

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		III.50	IV. 0	IV.10	IV.20	IV.30	IV.40	IV.50
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	17,75	18,04	18,35	18,67	19,02	19,40	19,80
	5	17,74	18,03	18,34	18,66	19,01	19,39	19,79
	10	17,62	17,91	18,22	18,54	18,88	19,25	19,65
	15	17,39	17,67	17,97	18,29	18,63	18,99	19,38
	20	17,03	17,31	17,60	17,92	18,25	18,61	18,99
	25	16,56	16,82	17,11	17,42	17,75	18,10	18,47
VII	+ 0	15,96	16,22	16,49	16,79	17,11	17,44	17,80
	5	15,24	15,49	15,75	16,03	16,33	16,65	16,99
	10	14,39	14,62	14,87	15,14	15,42	15,72	16,04
	15	13,41	13,63	13,86	14,11	14,37	14,65	14,95
	20	12,31	12,51	12,72	12,95	13,19	13,45	13,73
	25	11,09	11,27	11,46	11,67	11,89	12,12	12,37
VIII	+ 0	9,76	9,92	10,09	10,27	10,46	10,66	10,88
	5	8,32	8,45	8,59	8,75	8,92	9,09	9,27
	10	6,78	6,89	7,01	7,14	7,27	7,41	7,56
	15	5,16	5,24	5,33	5,43	5,53	5,64	5,76
	20	3,48	3,54	3,60	3,66	3,73	3,80	3,88
	25	1,75	1,78	1,81	1,84	1,88	1,91	1,95
IX	– 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,75	1,78	1,81	1,84	1,88	1,92	1,95
	10	3,48	3,54	3,60	3,66	3,73	3,81	3,89
	15	5,17	5,26	5,35	5,44	5,54	5,65	5,77
	20	6,80	6,91	7,03	7,16	7,29	7,43	7,59
	25	8,36	8,49	8,63	8,79	8,95	9,12	9,31
X	– 0	9,81	9,97	10,14	10,32	10,51	10,72	10,94
	5	11,16	11,34	11,54	11,74	11,96	12,20	12,45
	10	12,40	12,60	12,82	13,05	13,29	13,55	13,83
	15	13,52	13,74	13,97	14,22	14,49	14,77	15,07
	20	14,51	14,74	14,99	15,26	15,55	15,86	16,18
	25	15,37	15,62	15,89	16,17	16,47	16,79	17,14
XI	– 0	16,11	16,37	16,65	16,95	17,26	17,60	17,96
	5	16,72	16,99	17,28	17,59	17,92	18,27	18,65
	10	17,21	17,49	17,79	18,10	18,44	18,80	19,19
	15	17,57	17,86	18,16	18,48	18,83	19,20	19,59
	20	17,81	18,10	18,41	18,74	19,09	19,46	19,86
	25	17,94	18,23	18,54	18,87	19,22	19,60	20,00
XII	– 0	17,95	18,24	18,55	18,88	19,23	19,61	20,01

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		V. 0	V. 10	V. 20	V. 30	V. 40	V. 50	VI. 0
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	20,22	20,67	21,15	21,67	22,22	22,81	23,43
	5	20,21	20,66	21,14	21,66	22,21	22,80	23,42
	10	20,07	20,52	21,00	21,51	22,05	22,64	23,26
	15	19,80	20,24	20,71	21,22	21,76	22,33	22,95
	20	19,40	19,83	20,29	20,79	21,32	21,88	22,48
	25	18,86	19,28	19,73	20,21	20,72	21,27	21,85
VII	+ 0	18,18	18,58	19,02	19,48	19,97	20,50	21,06
	5	17,35	17,74	18,15	18,60	19,07	19,57	20,11
	10	16,38	16,75	17,14	17,56	18,00	18,48	18,99
	15	15,27	15,61	15,98	16,37	16,78	17,23	17,70
	20	14,03	14,34	14,67	15,03	15,41	15,82	16,25
	25	12,64	12,92	13,22	13,54	13,88	14,25	14,65
VIII	+ 0	11,11	11,36	11,63	11,91	12,21	12,54	12,89
	5	9,47	9,68	9,91	10,15	10,41	10,68	10,98
	10	7,72	7,89	8,08	8,28	8,49	8,71	8,95
	15	5,88	6,01	6,15	6,30	6,46	6,63	6,81
	20	3,96	4,05	4,14	4,24	4,35	4,47	4,59
	25	1,99	2,04	2,09	2,14	2,19	2,25	2,31
IX	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	1,99	2,04	2,09	2,14	2,19	2,25	2,31
	10	3,97	4,06	4,15	4,25	4,36	4,48	4,60
	15	5,89	6,02	6,17	6,32	6,48	6,65	6,83
	20	7,75	7,92	8,11	8,31	8,52	8,74	8,98
	25	9,51	9,72	9,95	10,19	10,45	10,73	11,02
X	− 0	11,17	11,42	11,69	11,97	12,28	12,60	12,94
	5	12,72	13,00	13,30	13,62	13,97	14,34	14,73
	10	14,12	14,44	14,78	15,14	15,52	15,93	16,37
	15	15,39	15,74	16,11	16,50	16,92	17,37	17,84
	20	16,52	16,89	17,29	17,71	18,16	18,64	19,15
	25	17,51	17,90	18,32	18,76	19,24	19,75	20,29
XI	− 0	18,35	18,76	19,19	19,66	20,16	20,69	21,26
	5	19,05	19,47	19,92	20,41	20,93	21,48	22,07
	10	19,60	20,04	20,50	21,00	21,54	22,11	22,72
	15	20,01	20,45	20,94	21,45	21,99	22,57	23,20
	20	20,28	20,73	21,22	21,74	22,29	22,88	23,52
	25	20,43	20,89	21,37	21,89	22,45	23,04	23,68
XII	− 0	20,44	20,90	21,38	21,90	22,46	23,05	23,69

TABLE II. *Equations to Equal Altitudes.*

☉'s Long.		Half Interval between the Observations.						
		H. M. I . 30	H. M. I. 40	H. M. I. 50	H. M. II. 0	H. M. II. 10	H. M. II. 20	H. M. II. 30
S.	D.	S.	S.	S.	S.	S.	S.	S.
O +	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
	5	0, 49	0, 49	0, 48	0, 47	0, 46	0, 45	0, 44
	10	0, 97	0, 96	0, 95	0, 93	0, 91	0, 90	0, 88
	15	1, 43	1, 41	1, 39	1, 36	1, 34	1, 31	1, 28
	20	1, 84	1, 82	1, 79	1, 76	1, 73	1, 70	1, 66
	25	2, 21	2, 18	2, 15	2, 12	2, 08	2, 04	1, 99
I +	0	2, 52	2, 49	2, 45	2, 41	2, 37	2, 32	2, 27
	5	2, 77	2, 73	2, 69	2, 65	2, 60	2, 55	2, 49
	10	2, 93	2, 89	2, 85	2, 81	2, 76	2, 70	2, 64
	15	3, 01	2, 97	2, 93	2, 88	2, 83	2, 77	2, 71
	20	3, 01	2, 97	2, 93	2, 88	2, 83	2, 77	2, 71
	25	2, 91	2, 87	2, 83	2, 78	2, 73	2, 67	2, 61
II +	0	2, 71	2, 68	2, 64	2, 60	2, 55	2, 50	2, 44
	5	2, 42	2, 39	2, 36	2, 32	2, 28	2, 23	2, 18
	10	2, 06	2, 03	2, 00	1, 97	1, 93	1, 89	1, 85
	15	1, 61	1, 59	1, 57	1, 54	1, 51	1, 48	1, 45
	20	1, 11	1, 10	1, 08	1, 06	1, 04	1, 02	1, 00
	25	0, 57	0, 56	0, 55	0, 54	0, 53	0, 52	0, 51
III —	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
	5	0, 56	0, 56	0, 55	0, 54	0, 53	0, 52	0, 51
	10	1, 11	1, 10	1, 08	1, 06	1, 04	1, 02	1, 00
	15	1, 61	1, 59	1, 57	1, 54	1, 51	1, 48	1, 45
	20	2, 05	2, 02	1, 99	1, 96	1, 92	1, 88	1, 84
	25	2, 41	2, 38	2, 35	2, 31	2, 27	2, 22	2, 17
IV —	0	2, 70	2, 66	2, 62	2, 58	2, 53	2, 48	2, 43
		2, 89	2, 85	2, 81	2, 76	2, 71	2, 66	2, 60
	10	2, 99	2, 95	2, 90	2, 85	2, 80	2, 75	2, 69
	15	2, 99	2, 95	2, 91	2, 86	2, 81	2, 75	2, 69
	20	2, 91	2, 87	2, 83	2, 78	2, 73	2, 68	2, 62
	25	2, 74	2, 70	2, 66	2, 62	2, 57	2, 52	2, 47
V —	0	2, 50	2, 47	2, 43	2, 39	2, 35	2, 30	2, 25
	5	2, 19	2, 16	2, 13	2, 09	2, 05	2, 01	1, 97
	10	1, 82	1, 80	1, 77	1, 74	1, 71	1, 68	1, 64
	15	1, 41	1, 39	1, 37	1, 35	1, 33	1, 30	1, 27
	20	0, 96	0, 95	0, 94	0, 92	0, 90	0, 88	0, 86
	25	0, 49	0, 48	0, 47	0, 47	0, 46	0, 45	0, 44
VI —	0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00

☉'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		II. 40	II. 50	III. 0	III.10	III.20	III.30	III.40
S.	D.	S.	S.	S.	S.	S.	S.	S.
♈	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,43	0,42	0,41	0,40	0,38	0,37	0,35
	10	0,85	0,83	0,81	0,78	0,75	0,72	0,69
	15	1,25	1,22	1,18	1,14	1,10	1,06	1,01
	20	1,62	1,58	1,53	1,48	1,43	1,37	1,31
	25	1,94	1,89	1,83	1,77	1,71	1,64	1,57
I	+ 0	2,21	2,15	2,09	2,02	1,95	1,87	1,79
	5	2,43	2,36	2,29	2,22	2,14	2,05	1,96
	10	2,57	2,50	2,43	2,35	2,26	2,17	2,08
	15	2,64	2,57	2,50	2,42	2,33	2,24	2,14
	20	2,64	2,57	2,49	2,41	2,32	2,23	2,13
	25	2,55	2,48	2,41	2,33	2,24	2,15	2,06
II	+ 0	2,38	2,31	2,24	2,17	2,09	2,01	1,92
	5	2,13	2,07	2,01	1,94	1,87	1,80	1,72
	10	1,80	1,75	1,70	1,65	1,59	1,53	1,46
	15	1,41	1,37	1,33	1,29	1,24	1,19	1,14
	20	0,98	0,95	0,92	0,89	0,86	0,83	0,79
	25	0,50	0,48	0,47	0,45	0,44	0,42	0,40
III	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,49	0,48	0,47	0,45	0,44	0,42	0,40
	10	0,97	0,94	0,91	0,88	0,85	0,82	0,78
	15	1,41	1,37	1,33	1,29	1,24	1,19	1,14
	20	1,80	1,75	1,70	1,64	1,58	1,52	1,45
	25	2,12	2,06	2,00	1,93	1,86	1,79	1,71
IV	− 0	2,37	2,30	2,23	2,16	2,08	2,00	1,91
	5	2,54	2,47	2,39	2,31	2,23	2,14	2,05
	10	2,62	2,55	2,47	2,39	2,31	2,22	2,12
	15	2,62	2,55	2,48	2,40	2,31	2,22	2,12
	20	2,55	2,48	2,41	2,33	2,25	2,16	2,06
	25	2,41	2,34	2,27	2,20	2,12	2,03	1,94
V	− 0	2,19	2,13	2,07	2,00	1,93	1,85	1,77
	5	1,92	1,87	1,81	1,75	1,69	1,62	1,55
	10	1,60	1,56	1,51	1,46	1,41	1,35	1,29
	15	1,24	1,21	1,17	1,13	1,09	1,05	1,00
	20	0,84	0,82	0,80	0,77	0,74	0,71	0,68
	25	0,43	0,42	0,40	0,39	0,38	0,36	0,35
VI	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		III.50	IV. 0	IV.10	IV.20	IV.30	IV.40	IV.50
S.	D.	S.	S.	S.	S.	S.	S.	S.
O	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,33	0,31	0,30	0,28	0,25	0,23	0,21
	10	0,66	0,62	0,58	0,54	0,50	0,46	0,41
	15	0,96	0,91	0,85	0,79	0,73	0,67	0,60
	20	1,24	1,17	1,10	1,03	0,95	0,87	0,78
	25	1,49	1,41	1,32	1,23	1,14	1,04	0,93
I	+ 0	1,70	1,61	1,51	1,41	1,30	1,18	1,66
	5	1,86	1,76	1,65	1,54	1,42	1,29	1,16
	10	1,98	1,87	1,76	1,64	1,51	1,37	1,23
	15	2,03	1,92	1,80	1,68	1,55	1,41	1,27
	20	2,03	1,92	1,80	1,68	1,55	1,41	1,26
	25	1,96	1,85	1,74	1,62	1,49	1,36	1,22
II	+ 0	1,83	1,73	1,62	1,51	1,39	1,27	1,14
	5	1,64	1,55	1,45	1,35	1,25	1,14	1,02
	10	1,39	1,31	1,23	1,15	1,06	0,96	0,86
	15	1,09	1,03	0,97	0,90	0,83	0,76	0,68
	20	0,75	0,71	0,67	0,62	0,57	0,52	0,47
	25	0,38	0,36	0,34	0,32	0,29	0,26	0,24
III	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,38	0,36	0,34	0,31	0,29	0,26	0,24
	10	0,75	0,71	0,67	0,62	0,57	0,52	0,47
	15	1,08	1,02	0,96	0,90	0,83	0,76	0,68
	20	1,38	1,31	1,23	1,14	1,05	0,96	0,86
	25	1,63	1,54	1,45	1,35	1,24	1,13	1,02
IV	− 0	1,82	1,72	1,61	1,50	1,38	1,26	1,13
	5	1,95	1,84	1,73	1,61	1,48	1,35	1,21
	10	2,01	1,90	1,79	1,67	1,54	1,40	1,26
	15	2,02	1,91	1,79	1,67	1,54	1,40	1,26
	20	1,96	1,85	1,74	1,62	1,49	1,36	1,22
	25	1,85	1,75	1,64	1,53	1,41	1,28	1,15
V	− 0	1,68	1,59	1,50	1,40	1,29	1,17	1,05
	5	1,48	1,40	1,31	1,22	1,13	1,03	0,92
	10	1,23	1,16	1,09	1,02	0,94	0,86	0,77
	15	0,95	0,90	0,85	0,79	0,73	0,66	0,59
	20	0,65	0,62	0,58	0,54	0,50	0,45	0,40
	25	0,33	0,31	0,29	0,27	0,25	0,23	0,21
VI	− 0	0,66	0,00	0,00	0,00	0,00	0,00	0,00

⊙'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		V. 0	V. 10	V. 20	V. 30	V. 40	V. 50	VI. 0
S.	D.	S.	S.	S.	S.	S.	S.	S.
0	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,18	0,16	0,13	0,10	0,07	0,04	0,00
	10	0,36	0,31	0,25	0,19	0,13	0,07	0,00
	15	0,53	0,45	0,37	0,29	0,20	0,10	0,00
	20	0,68	0,58	0,48	0,37	0,25	0,13	0,00
	25	0,82	0,70	0,57	0,44	0,30	0,16	0,00
I	+ 0	0,93	0,80	0,66	0,51	0,35	0,18	0,00
	5	1,02	0,87	0,71	0,55	0,38	0,19	0,00
	10	1,08	0,92	0,76	0,59	0,41	0,21	0,00
	15	1,12	0,95	0,78	0,60	0,41	0,21	0,00
	20	1,11	0,95	0,78	0,60	0,41	0,21	0,00
	25	1,07	0,91	0,75	0,58	0,40	0,20	0,00
II	+ 0	1,00	0,85	0,70	0,54	0,37	0,19	0,00
	5	0,90	0,77	0,63	0,48	0,33	0,17	0,00
	10	0,76	0,65	0,53	0,41	0,28	0,14	0,00
	15	0,60	0,51	0,42	0,32	0,22	0,11	0,00
	20	0,41	0,35	0,29	0,22	0,15	0,08	0,00
	25	0,21	0,18	0,15	0,11	0,08	0,04	0,00
III	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,21	0,18	0,15	0,11	0,08	0,04	0,00
	10	0,41	0,35	0,29	0,22	0,15	0,08	0,00
	15	0,60	0,51	0,42	0,32	0,22	0,11	0,00
	20	0,76	0,65	0,53	0,41	0,28	0,14	0,00
	25	0,90	0,77	0,63	0,48	0,33	0,17	0,00
IV	− 0	0,99	0,85	0,70	0,54	0,37	0,19	0,00
	5	1,06	0,91	0,75	0,58	0,40	0,20	0,00
	10	1,11	0,95	0,78	0,60	0,41	0,21	0,00
	15	1,11	0,95	0,78	0,60	0,41	0,21	0,00
	20	1,10	0,92	0,76	0,58	0,39	0,20	0,00
	25	1,01	0,86	0,71	0,55	0,38	0,19	0,00
V	− 0	0,92	0,79	0,65	0,50	0,34	0,17	0,00
	5	0,81	0,69	0,57	0,44	0,30	0,15	0,00
	10	0,68	0,58	0,47	0,36	0,25	0,13	0,00
	15	0,52	0,45	0,37	0,28	0,19	0,10	0,00
	20	0,35	0,30	0,25	0,19	0,13	0,07	0,00
	25	0,18	0,15	0,13	0,10	0,07	0,04	0,00
VI	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00

☉'s Long.		Half Interval between the Observations.						
		H. M. I. 30	H. M. I. 40	H. M. I. 50	H. M. II. 0	H. M. II. 10	H. M. II. 20	H. M. II. 30
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
	5	0, 49	0, 48	0, 48	0, 47	0, 46	0, 45	0, 44
	10	0, 97	0, 96	0, 95	0, 93	0, 91	0, 89	0, 87
	15	1, 43	1, 42	1, 40	1, 37	1, 35	1, 32	1, 29
	20	1, 86	1, 84	1, 81	1, 78	1, 75	1, 72	1, 68
	25	2, 25	2, 22	2, 19	2, 15	2, 11	2, 07	2, 03
VII	+ 0	2, 58	2, 55	2, 51	2, 47	2, 43	2, 38	2, 33
	5	2, 85	2, 81	2, 77	2, 72	2, 67	2, 62	2, 56
	10	3, 04	3, 00	2, 95	2, 90	2, 85	2, 79	2, 73
	15	3, 14	3, 10	3, 05	3, 00	2, 94	2, 88	2, 82
	20	3, 14	3, 10	3, 06	3, 01	2, 95	2, 89	2, 83
	25	3, 05	3, 01	2, 97	2, 92	2, 87	2, 81	2, 75
VIII	+ 0	2, 86	2, 82	2, 78	2, 73	2, 68	2, 63	2, 57
	5	2, 57	2, 53	2, 49	2, 45	2, 41	2, 36	2, 31
	10	2, 18	2, 15	2, 12	2, 08	2, 05	2, 01	1, 96
	15	1, 71	1, 69	1, 67	1, 64	1, 61	1, 58	1, 54
	20	1, 18	1, 17	1, 15	1, 13	1, 11	1, 09	1, 06
	25	0, 60	0, 60	0, 59	0, 58	0, 57	0, 55	0, 54
IX	− 0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00
	5	0, 60	0, 60	0, 59	0, 58	0, 57	0, 55	0, 54
	10	1, 18	1, 17	1, 15	1, 13	1, 11	1, 09	1, 06
	15	1, 72	1, 70	1, 67	1, 64	1, 61	1, 58	1, 54
	20	2, 19	2, 16	2, 13	2, 09	2, 05	2, 01	1, 97
	25	2, 58	2, 54	2, 50	2, 46	2, 42	2, 37	2, 32
X	− 0	2, 87	2, 83	2, 79	2, 79	2, 70	2, 64	2, 58
	5	3, 06	3, 03	2, 99	2, 94	2, 88	2, 82	2, 76
	10	3, 16	3, 12	3, 08	3, 03	2, 97	2, 91	2, 85
	15	3, 16	3, 12	3, 07	3, 02	2, 97	2, 91	2, 84
	20	3, 06	3, 02	2, 98	2, 93	2, 88	2, 82	2, 76
	25	2, 87	2, 84	2, 80	2, 75	2, 70	2, 64	2, 58
XI	− 0	2, 60	2, 57	2, 54	2, 50	2, 45	2, 40	2, 35
	5	2, 27	2, 24	2, 21	2, 18	2, 14	2, 10	2, 05
	10	1, 88	1, 86	1, 83	1, 80	1, 77	1, 73	1, 69
	15	1, 45	1, 43	1, 41	1, 39	1, 36	1, 33	1, 30
	20	0, 99	0, 97	0, 96	0, 94	0, 92	0, 90	0, 88
	25	0, 50	0, 49	0, 48	0, 47	0, 47	0, 46	0, 45
XII	− 0	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00

☉'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		II. 40	II. 50	III. 0	III.10	III.20	III.30	III.40
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,43	0,42	0,41	0,39	0,38	0,36	0,35
	10	0,85	0,83	0,81	0,78	0,75	0,72	0,69
	15	1,26	1,22	1,19	1,15	1,11	1,06	1,02
	20	1,64	1,59	1,54	1,49	1,44	1,38	1,32
	25	1,98	1,92	1,86	1,80	1,74	1,67	1,60
VII	+ 0	2,27	2,21	2,14	2,07	2,00	1,92	1,83
	5	2,50	2,43	2,36	2,28	2,20	2,11	2,02
	10	2,66	2,59	2,55	2,43	2,34	2,25	2,15
	15	2,75	2,68	2,60	2,51	2,42	2,32	2,22
	20	2,76	2,68	2,60	2,52	2,43	2,33	2,23
	25	2,68	2,60	2,52	2,44	2,35	2,26	2,16
VIII	+ 0	2,51	2,44	2,37	2,29	2,21	2,12	2,03
	5	2,25	2,19	2,12	2,05	1,98	1,90	1,82
	10	1,91	1,86	1,81	1,75	1,69	1,62	1,55
	15	1,50	1,46	1,42	1,37	1,32	1,27	1,22
	20	1,04	1,01	0,98	0,95	0,91	0,88	0,84
	25	0,53	0,51	0,50	0,48	0,47	0,45	0,43
IX	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,53	0,51	0,50	0,48	0,47	0,45	0,43
	10	1,04	1,01	0,98	0,95	0,91	0,88	0,84
	15	1,51	1,47	1,42	1,38	1,33	1,27	1,22
	20	1,92	1,87	1,81	1,75	1,69	1,62	1,55
	25	2,26	2,20	2,13	2,06	1,99	1,91	1,83
X	− 0	2,52	2,45	2,38	2,30	2,22	2,13	2,04
	5	2,69	2,62	2,54	2,46	2,37	2,28	2,18
	10	2,78	2,70	2,62	2,53	2,44	2,34	2,24
	15	2,77	2,70	2,62	2,53	2,44	2,34	2,24
	20	2,69	2,61	2,53	2,45	2,36	2,27	2,17
	25	2,52	2,45	2,38	2,30	2,22	2,13	2,04
XI	− 0	2,29	2,23	2,16	2,09	2,01	1,93	1,85
	5	2,00	1,94	1,88	1,82	1,76	1,69	1,61
	10	1,65	1,61	1,56	1,51	1,46	1,40	1,34
	15	1,27	1,24	1,20	1,16	1,12	1,08	1,03
	20	0,86	0,84	0,81	0,79	0,76	0,73	0,70
	25	0,43	0,42	0,41	0,40	0,38	0,37	0,35
XII	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00

⊙'s Long.		Half Interval between the Observations.						
		H. M. III.50	H. M. IV. 0	H. M. IV.10	H. M. IV.20	H. M. IV.30	H. M. IV.40	H. M. IV.50
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,33	0,31	0,29	0,27	0,25	0,23	0,21
	10	0,66	0,62	0,58	0,54	0,50	0,46	0,41
	15	0,97	0,91	0,86	0,80	0,74	0,67	0,60
	20	1,26	1,19	1,12	1,04	0,96	0,87	0,78
	25	1,52	1,44	1,35	1,26	1,16	1,06	0,95
VII	+ 0	1,74	1,65	1,55	1,44	1,33	1,21	1,09
	5	1,92	1,82	1,71	1,59	1,47	1,34	1,20
	10	2,05	1,94	1,82	1,69	1,56	1,42	1,28
	15	2,11	2,00	1,88	1,75	1,61	1,47	1,32
	20	2,12	2,00	1,88	1,75	1,62	1,47	1,32
	25	2,06	1,95	1,83	1,70	1,57	1,43	1,28
VIII	+ 0	1,93	1,82	1,71	1,59	1,47	1,34	1,20
	5	1,73	1,63	1,53	1,43	1,32	1,20	1,08
	10	1,47	1,39	1,31	1,22	1,12	1,02	0,92
	15	1,16	1,09	1,02	0,96	0,88	0,80	0,72
	20	0,80	0,75	0,71	0,66	0,61	0,55	0,50
	25	0,41	0,38	0,36	0,34	0,31	0,28	0,25
IX	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,41	0,38	0,36	0,34	0,31	0,28	0,25
	10	0,80	0,75	0,71	0,66	0,61	0,55	0,50
	15	1,16	1,10	1,03	0,96	0,88	0,80	0,72
	20	1,47	1,39	1,31	1,22	1,13	1,03	0,92
	25	1,74	1,64	1,54	1,44	1,33	1,21	1,08
X	− 0	1,94	1,83	1,72	1,60	1,48	1,35	1,21
	5	2,07	1,96	1,84	1,71	1,58	1,44	1,29
	10	2,13	2,02	1,90	1,77	1,63	1,48	1,33
	15	2,13	2,01	1,89	1,76	1,62	1,48	1,33
	20	2,06	1,95	1,83	1,71	1,58	1,44	1,29
	25	1,94	1,83	1,72	1,60	1,48	1,35	1,21
XI	− 0	1,76	1,66	1,56	1,45	1,34	1,22	1,09
	5	1,53	1,45	1,36	1,27	1,17	1,07	0,96
	10	1,27	1,20	1,13	1,05	0,97	0,88	0,79
	15	0,98	0,93	0,87	0,81	0,75	0,68	0,61
	20	0,66	0,63	0,59	0,55	0,51	0,46	0,41
	25	0,33	0,32	0,30	0,28	0,26	0,23	0,21
XII	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00

TABLE II. *Equations to Equal Altitudes.*

☉'s Long.		Half Interval between the Observations.						
		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	H. M.
		V. 0	V. 10	V. 20	V. 30	V. 40	V. 50	VI. 0
S.	D.	S.	S.	S.	S.	S.	S.	S.
VI	+ 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,18	0,15	0,13	0,10	0,07	0,04	0,00
	10	0,36	0,31	0,25	0,19	0,13	0,07	0,00
	15	0,53	0,45	0,37	0,29	0,20	0,10	0,00
	20	0,69	0,59	0,48	0,37	0,26	0,13	0,00
	25	0,83	0,71	0,58	0,45	0,31	0,16	0,00
VII	+ 0	0,96	0,82	0,67	0,52	0,35	0,18	0,00
	5	1,05	0,90	0,74	0,57	0,39	0,20	0,00
	10	1,12	0,96	0,79	0,61	0,42	0,21	0,00
	15	1,16	0,99	0,81	0,63	0,43	0,22	0,00
	20	1,16	0,99	0,82	0,63	0,43	0,22	0,00
	25	1,13	0,96	0,79	0,61	0,42	0,21	0,00
VIII	+ 0	1,05	0,90	0,74	0,57	0,39	0,20	0,00
	5	0,95	0,81	0,66	0,51	0,35	0,18	0,00
	10	0,81	0,69	0,57	0,44	0,30	0,15	0,00
	15	0,63	0,54	0,44	0,34	0,23	0,12	0,00
	20	0,44	0,37	0,31	0,24	0,16	0,08	0,00
	25	0,22	0,19	0,16	0,12	0,08	0,04	0,00
IX	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	5	0,22	0,19	0,16	0,12	0,08	0,04	0,00
	10	0,44	0,37	0,31	0,24	0,16	0,08	0,00
	15	0,64	0,55	0,45	0,35	0,24	0,12	0,00
	20	0,81	0,69	0,57	0,44	0,30	0,15	0,00
	25	0,95	0,81	0,67	0,51	0,35	0,18	0,00
X	− 0	1,06	0,91	0,75	0,57	0,39	0,20	0,00
	5	1,13	0,97	0,80	0,61	0,42	0,22	0,00
	10	1,17	1,00	0,82	0,63	0,43	0,22	0,00
	15	1,17	1,00	0,82	0,63	0,43	0,22	0,00
	20	1,13	0,96	0,79	0,61	0,42	0,21	0,00
	25	1,06	0,91	0,75	0,57	0,39	0,20	0,00
XI	− 0	0,96	0,82	0,67	0,52	0,36	0,18	0,00
	5	0,84	0,72	0,59	0,45	0,31	0,16	0,00
	10	0,70	0,60	0,49	0,38	0,26	0,13	0,00
	15	0,54	0,46	0,38	0,29	0,20	0,10	0,00
	20	0,36	0,31	0,25	0,19	0,13	0,07	0,00
	25	0,18	0,16	0,13	0,10	0,07	0,04	0,00
XII	− 0	0,00	0,00	0,00	0,00	0,00	0,00	0,00

TABLE III. *For Reducing the Sun's Longitude, as given in the Nautical Almanac for Noon at Greenwich, to Noon under any other Meridian.*

Time from Noon.	Hourly Motion of the Sun.											Lon.
	′ ″ 2 23	′ ″ 2 24	′ ″ 2 25	′ ″ 2 26	′ ″ 2 27	′ ″ 2 28	′ ″ 2 29	′ ″ 2 30	′ ″ 2 31	′ ″ 2 32	′ ″ 2 33	
H ′	′	′	′	′	′	′	′	′	′	′	′	
0. 20	0, 8	0, 8	0, 8	0, 8	0, 8	0, 8	0, 8	0, 8	0, 8	0, 8	0, 8	5
0. 40	1, 6	1, 6	1, 6	1, 6	1, 6	1, 6	1, 7	1, 7	1, 7	1, 7	1, 7	10
1. 00	2, 4	2, 4	2, 4	2, 4	2, 5	2, 5	2, 5	2, 5	2, 5	2, 5	2, 5	15
1. 20	3, 2	3, 2	3, 2	3, 2	3, 3	3, 3	3, 3	3, 3	3, 4	3, 4	3, 4	20
1. 40	4, 0	4, 0	4, 0	4, 0	4, 1	4, 1	4, 1	4, 2	4, 2	4, 2	4, 2	25
2. 00	4, 8	4, 8	4, 8	4, 8	4, 9	4, 9	5, 0	5, 0	5, 0	5, 1	5, 1	30
2. 20	5, 6	5, 6	5, 6	5, 6	5, 7	5, 7	5, 8	5, 8	5, 9	5, 9	5, 9	35
2. 40	6, 4	6, 4	6, 4	6, 4	6, 5	6, 6	6, 6	6, 7	6, 7	6, 7	6, 8	40
3. 00	7, 2	7, 2	7, 2	7, 3	7, 4	7, 4	7, 5	7, 5	7, 6	7, 6	7, 6	45
3. 20	8, 0	8, 0	8, 1	8, 1	8, 2	8, 2	8, 3	8, 3	8, 4	8, 4	8, 5	50
3. 40	8, 8	8, 8	8, 9	8, 9	9, 0	9, 0	9, 1	9, 2	9, 2	9, 3	9, 3	55
4. 00	9, 6	9, 6	9, 7	9, 7	9, 8	9, 9	9, 9	10, 0	10, 1	10, 1	10, 2	60
4. 20	10, 4	10, 4	10, 5	10, 5	10, 6	10, 7	10, 8	10, 8	10, 9	11, 0	11, 0	65
4. 40	11, 2	11, 2	11, 3	11, 3	11, 4	11, 5	11, 6	11, 7	11, 7	11, 8	11, 9	70
5. 00	12, 0	12, 0	12, 1	12, 1	12, 2	12, 3	12, 4	12, 5	12, 6	12, 7	12, 7	75
5. 20	12, 8	12, 8	12, 9	12, 9	13, 1	13, 2	13, 2	13, 3	13, 4	13, 5	13, 6	80
5. 40	13, 6	13, 6	13, 7	13, 8	13, 9	14, 0	14, 1	14, 2	14, 3	14, 4	14, 4	85
6. 00	14, 3	14, 4	14, 5	14, 6	14, 7	14, 8	14, 9	15, 0	15, 1	15, 2	15, 3	90
6. 20	15, 1	15, 2	15, 3	15, 4	15, 5	15, 6	15, 7	15, 8	15, 9	16, 0	16, 1	95
6. 40	15, 9	16, 0	16, 1	16, 2	16, 3	16, 4	16, 5	16, 7	16, 8	16, 9	17, 0	100
7. 00	16, 7	16, 8	16, 9	17, 0	17, 2	17, 3	17, 4	17, 5	17, 6	17, 7	17, 8	105
7. 20	17, 5	17, 6	17, 7	17, 8	18, 0	18, 1	18, 2	18, 3	18, 5	18, 6	18, 7	110
7. 40	18, 3	18, 4	18, 5	18, 6	18, 8	18, 9	19, 0	19, 2	19, 3	19, 4	19, 5	115
8. 00	19, 1	19, 2	19, 3	19, 4	19, 6	19, 7	19, 8	20, 0	20, 1	20, 3	20, 4	120
8. 20	19, 9	20, 0	20, 1	20, 2	20, 4	20, 5	20, 7	20, 8	21, 0	21, 1	21, 2	125
8. 40	20, 7	20, 8	20, 9	21, 0	21, 2	21, 4	21, 5	21, 7	21, 8	21, 9	22, 1	130
9. 00	21, 5	21, 6	21, 7	22, 8	22, 1	22, 2	22, 3	22, 5	22, 6	22, 8	22, 9	135
9. 20	22, 3	22, 4	22, 5	22, 7	22, 9	23, 0	23, 2	23, 3	23, 5	23, 6	23, 8	140
9. 40	23, 1	23, 2	23, 3	23, 5	23, 7	23, 8	24, 0	24, 2	24, 3	24, 5	24, 6	145
10. 00	23, 9	24, 0	24, 1	24, 3	24, 5	24, 7	24, 8	25, 0	25, 2	25, 3	25, 5	150
10. 20	24, 7	24, 8	24, 9	25, 1	25, 3	25, 5	25, 7	25, 8	26, 0	26, 2	26, 3	155
10. 40	25, 5	25, 6	25, 8	25, 9	26, 1	26, 3	26, 5	26, 7	26, 8	27, 0	27, 2	160
11. 00	26, 3	26, 4	26, 6	26, 7	27, 0	27, 1	27, 3	27, 5	27, 7	27, 9	28, 0	165
11. 20	27, 1	27, 2	27, 4	27, 5	27, 8	27, 9	28, 1	28, 3	28, 5	28, 7	28, 9	170
11. 40	27, 9	28, 0	28, 2	28, 3	28, 6	28, 8	29, 0	29, 2	29, 4	29, 6	29, 7	175
12. 00	28, 6	28, 8	29, 0	29, 2	29, 4	29, 6	29, 8	30, 0	30, 2	30, 4	30, 6	180

TABLE IV. *Proper Stars for bringing a Tranſit Inſtrument into the Plane of the Meridian.*

Names of the Stars.	Right Aſc. in Time.	An. var. in right Aſc.	Declination.	An. var. in Declina.
	H. M. S.	S.	D. M. S.	S.
θ Eridani	2. 50. 30, 1	2, 28	41. 7. 58 S.	−14, 75
β Perſei	2. 54. 53, 1	3, 85	40. 9. 14 N.	+14, 49
β Columbæ	5. 43. 44, 7	2, 10	35. 51. 53 S.	− 1, 42
θ Aurigæ	5. 45. 44, 1	4, 08	37. 10. 54 N.	+ 1, 25
η Canis Majoris	7. 15. 59, 6	2, 37	28. 54. 44 S.	+ 6, 53
Pollux	7. 32. 47, 1	3, 74	28. 30. 30 N.	− 7, 89
q Navis	10. 6. 6, 8	2, 51	41. 6. 47 S.	+17, 62
μ Urſæ Majoris	10. 10. 4, 2	3, 63	42. 31. 29 N.	−17, 78
η Centauri	12. 42. 7, 7	3, 27	39. 3. 56 S.	+19, 71
186 Urſæ Majoris	12. 46. 25, 6	2, 85	39. 25. 41 N.	−19, 64
η Centauri	14. 22. 33, 0	3, 75	41. 14. 45 S.	+16, 29
γ Bootes	14. 23. 49, 0	2, 43	39. 12. 37 N.	−16, 23
κ Centauri	14. 45. 53, 5	3, 84	41. 16. 5 S.	+15, 02
β Bootes	14. 54. 13, 8	2, 26	41. 12. 20 N.	−14, 53
ζ Herculis	16. 33. 35, 6	2, 29	31. 58. 44 N.	− 7, 39
ε Scorpii	16. 36. 56, 7	3, 91	33. 54. 6 S.	+ 7, 11
β Lyræ	18. 42. 31, 2	2, 21	33. 8. 19 N.	+ 3, 70
ζ Sagittarii	18. 49. 33, 9	3, 83	30. 9. 23 S.	− 4, 30
γ Lyræ	18. 51. 16, 4	2, 24	32. 25. 6 N.	+ 4, 45
τ Sagittarii	18. 54. 7, 7	3, 76	27. 57. 5 S.	− 4, 68
α Microſcopii	20. 37. 8, 0	3, 78	34. 31. 37 S.	−12, 70
ε Cygni	20. 37. 53, 0	2, 39	33. 12. 21 N.	+12, 75
Fomalhaut	22. 46. 16, 6	3, 32	30. 42. 9 S.	−19, 02
β Pegaſi	22. 53. 51, 2	2, 87	26. 58. 20 N.	+19, 22
δ Sculptoris	23. 38. 13, 6	3, 14	29. 15. 46 S.	−19, 96
α Andromedæ	23. 57. 48, 5	3, 06	27. 57. 41 N.	+20, 04

The Places of the Stars in this Table, are given for the Beginning of the Year 1795. They muſt be reduced to the Time they are wanted for, by multiplying the annual Variation by the Number of Years and Parts of a Year which have elapſed, and adding the Product to the Right Aſcenſion in the Table: but it muſt be added to, or ſubtracted from the Declination, according as the Sign + or — is annexed to it.

TABLE V. *For calculating the Deviation of Stars in Right Ascension.*

Star's right Ascension.	0 Signs. —		1 Signs. —		2 Signs. —		Star's right Ascension.
	6 Signs. —		7 Signs. —		8 Signs. —		
°	° ′	Log.	° ′	Log.	° ′	Log.	°
0	0. 0	9.804	6.45	9.778	7.48	9.716	30
1	0.15	9.804	6.54	9.777	7.41	9.713	29
2	0.31	9.804	7. 3	9.775	7.32	9.711	28
3	0.46	9.804	7.12	9.773	7.23	9.709	27
4	1. 1	9.803	7.20	9.771	7.14	9.707	26
5	1.16	9.803	7.28	9.770	7. 4	9.705	25
6	1.32	9.803	7.36	9.768	6.53	9.703	24
7	1.47	9.802	7.43	9.766	6.41	9.701	23
8	2. 2	9.802	7.49	9.764	6.29	9.699	22
9	2.17	9.802	7.55	9.762	6.17	9.697	21
10	2.31	9.801	8. 1	9.760	6. 3	9.695	20
11	2.46	9.801	8. 6	9.758	5.49	9.693	19
12	3. 0	9.800	8.10	9.756	5.35	9.692	18
13	3.15	9.799	8.14	9.754	5.20	9.690	17
14	3.29	9.798	8.17	9.751	5. 4	9.689	16
15	3.43	9.797	8.20	9.749	4.48	9.687	15
16	3.57	9.797	8.22	9.747	4.31	9.686	14
17	4.11	9.796	8.24	9.745	4.14	9.684	13
18	4.24	9.795	8.25	9.743	3.56	9.683	12
19	4.37	9.794	8.25	9.740	3.38	9.682	11
20	4.50	9.792	8.25	9.738	3.20	9.681	10
21	5. 3	9.791	8.25	9.736	3. 1	9.680	9
22	5.16	9.790	8.23	9.734	2.41	9.679	8
23	5.28	9.789	8.21	9.731	2.22	9.678	7
24	5.40	9.787	8.18	9.729	2. 2	9.678	6
25	5.51	9.786	8.15	9.727	1.42	9.677	5
26	6. 3	9.784	8.11	9.724	1.22	9.677	4
27	6.14	9.783	8. 6	9.722	1. 2	9.676	3
28	6.24	9.781	8. 1	9.720	0.42	9.676	2
29	6.35	9.780	7.55	9.718	0.21	9.676	1
30	6.45	9.778	7.48	9.716	0. 0	9.676	0
	11 Signs. +		10 Signs. +		9 Signs. +		
	5 Signs. +		4 Signs. +		3 Signs. +		

Erratum

p. 65, 66, 67. for 3′ 56″ 55 read 3′ 55″ 91.

[illegible]d.